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[ 621 .33 (.83) & 625 .3 (.83) ]

# Short memorandum on the electrification of the Chilian Section of the Transandine Railway Company,

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## I. — General.

One of the most interesting mountain railway lines in existence is that which connects the Chilian and the Argentine Republics and which is known as the Transandine Railway.

Starting from Los Andes on the Chilian side 834 m. (2 736 feet) above sea level, it wends its way eastwards over a circuitous route abounding in heavy grades, sharp curves, tunnels and snow sheds to a height of 3 207 m. (10 522 feet), where it traverses the Andes through a tunnel 3.2 km. (1.9 miles) long and descends to Mendoza on the Argentine side, 768 m. (2 520 feet) above sea level.

The total length of the line is 249.5 km. (155 miles), of which 70.5 km. (43.8 miles) are in Chilian territory and 179 km. (111.2 miles) in Argentine territory.

Although on the Chilian side the average grade is 34 °/₀₀ the contour of the country from km. 35 onward is such that five rack sections had to be constructed, the heaviest grade being 80 °/₀₀ over a distance of about 1.75 km. (1.10 miles). The maximum grade for all adhesion sections is limited to 25 °/₀₀.

On the Argentine side the more gentle eastern slope of the Andes imposed conditions of a less onerous nature, necessitating a maximum rack grade of 61 °/₀₀.

From the standpoint of haulage, the line can be divided into three main sections as shewn on the following table.

Sections A and C are adhesion only whereas section B, made up of alternate rack and adhesion sections, constitutes by far the most difficult portion of the system.

To operate over the sections A and C, an ordinary locomotive satisfies the conditions, but section B necessitates a special type of locomotive which must be capable of doing work on the rack and running rails simultaneously.

Due to the relatively short adhesion distance between Los Andes and Rio

Blanco, the trains are operated over the entire Chilian section between Los Andes and Las Cuevas by combined adhesion and rack locomotives.

The operation of the line between Los Andes and Zanjon Amarillo has presented many difficulties, the principal source of trouble being snow and avalanches in the higher altitudes, which for months at a time have completely stopped traffic during the winter season. To eliminate any further chance of such prolonged traffic interruptions, an extensive construction programme has been initiated to install additional snow and avalanche protection.

| — | Route distance, in metres (in miles). | Grades in millimetres per metre | | Curves. |
|---|---|---|---|---|
| | | Maximum. | Average. | Minimum radius, in metres (in chains). |
| **A. — Los Andes to Rio Blanco (Chili).** | | | | |
| All Adhesion . . . . . | 34 000 (21) | 25 | 17.2 | 100 (5) |
| **B. — Rio Blanco (Chili) to Zanjon Amarillo (Argentine).** | | | | |
| This consists of a series of eleven rack sections interconnected by adhesion sections. | | | | |
| *a*) Chili. | | | | |
| 1) Rack. — Total of five sections. . . . . | 21 456 (13.332) | 80 | 69.5 | 200 (10) |
| 2) Adhesion. . . . . | 15 100 (9.383) | 25 | 20 | 150 7.5) |
| *Total Chili.* . . | 36 556 (22.715) | | | |
| *b*) Argentine. | | | | |
| 1) Rack. — Total of six sections. . . . . | 13 401 (8.327) | 61 | 48.6 | 180 (9) |
| 2) Adhesion. . . . . | 32 549 (20.225) | 25 | 10.6 | 100 (5) |
| *Total Argentine.* . . | 45 950 (28.552) | | | |
| *Total Chili and Argentine.* . . | 82 506 (51.267) | | | |
| **C. — Zanjon Amarillo to Mendoza (Argentine).** | | | | |
| All adhesion. . . . . | 133 000 (82.6) | 27.3 | 10.9 | 100 (5) |

Some of the existing snow sheds have been lengthened and in various places a series of existing sheds and tunnels will be interconnected by snow sheds, these forming continuous tunnels of considerable length.

The longest of these combined tunnels and sheds on the Chilian side will, when completed, cover a distance of 1 1/2 km. (0.93 mile) and is located on a 7 % rack grade. A steam locomotive on such a grade would work at its maximum capacity and lowest speed and would require about eight minutes to run through this tunnel. To operate by steam under such a condition would be not only distressing, but would incur a very grave risk of asphyxiating the passengers and train staff.

With regard to the much longer summit tunnel, the grades are small and therefore the steam locomotive can run through it under comparatively light steaming, which makes the gas and smoke condition still bearable.

Realising that the advantages of the additional snow shed protection would, to a very large extent, be offset by the dangerous conditions of gas and smoke in the long tunnels on steep grades if steam traction were to be retained, it was decided to investigate the advisability of introducing electric traction.

After going thoroughly into all the factors, it was evident that the introduction of electric traction presented the following advantages :

*a*) Absence of smoke and gases, which will make it possible to entirely enclose long sections of the line by galpones and tunnels as above referred to, so as to form sufficient protection against interruption of traffic due to avalanches in winter and mud runs in spring, and thus keep the line open for traffic the year round. This is not possible with steam traction. Until the line is operated electrically some sections of the long artificial tunnels will have to be left open for ventilation purposes;

*b*) A cleaner, more comfortable and faster service;

*c*) Considerable operating economies.

In view of these advantages, the Chilian Company decided to adopt electrification at once for its heavy grade section from Rio Blanco as far as Las Cuevas on the Argentine side, which station is the present operating terminus of Chilian trains.

This work should be completed towards the latter part of 1926.

### II. — Haulage capacities of locomotives.

The limitations of one metre gauge impose severe restrictions on the design of an ordinary steam locomotive and these restrictions become especially severe when a combined rack and adhesion locomotive has to be considered. The present steam locomotives of the large type were designed to haul a train weight of 140 tons over the rack sections, but for various reasons the rating had to be reduced to 110/120 tons. The heaviest type of steam locomotive for rack working on the Chilian side weighs loaded 88 tons, that is when carrying its full equipment of water and fuel. Thus on the fully loaded basis the locomotive weighs about 73/80 % as much as the train hauled.

The electric locomotives will weigh about 84 tons and will be designed to haul 150 tons up the Chilian grade at speeds considerably greater than those possible with steam locomotives hauling much lighter trains. This haulage capacity will be maintained, since the power of an electric locomotive is not subject to reduction by wear, fouling or inefficient setting of valve gear, nor are they affected by cold weather conditions as is the case with steam locomotives.

This increased haulage capacity, coupled with the considerably saving in time, will be a very marked improvement over existing conditions.

### III. — Technical features.

a) *Power supply.* — The energy for operating the railway will be derived from the Cia. Chilena de Electricidad Limitada, from its hydro-electric plants. This Company is at present supplying the motive power for the electrified lines of the Chilian State Railways. The energy will be received by the Railway at Los Andes in the form of three-phase current at a pressure of 42 000 volts and periodicity of 50 cycles. The Railway is responsible for the erection and maintenance of the high tension transmission line from Los Andes to its substations.

b) *System of traction.* — In view of the physical restrictions along the line, advisability of keeping down locomotive weights and the nature of power supply, the system of traction best suited to the particular conditions prevailing is 3 000 volts direct current. This is the same as at present used by the Chilian State Railways.

c) *Substation.* — To utilise the energy supplied by the Power Company for the requirements of 3 000 volt D. C. traction, the high tension 42 000 volts, three-phase current will be stepped down and converted to 3 000 volts D. C. For this purpose one substation will be installed to feed the first electrified section. This substation will be equipped with two 1 500 kw. motor-generator converting units (one in reserve).

d) *Secondary distribution.* — The overhead conducting system for supplying the power from the substations to the locomotives will consist of the well-known catenary system.

The copper trolley wire, from which the locomotives will collect current, will have a cross section of 107 mm² (0.1658 square inch) and will under normal conditions, be suspended at a height of 5.5 metres (18 feet) above the rail level. The messenger cable acting as feeder, supports the trolley wire in a flexible manner. This cable will be carried on a porcelain insulator, which on single track line, will be fastened to a bracket arm attached to a steel pole. The suspension for two or more tracks will be of the cross catenary type and in tunnels special means will be adopted for supporting the messenger cables.

e) *Locomotives.* — The heavy type of steam locomotives at present in use weigh, fully loaded, 88 tons for the Chilian side. The maximum axle loadings are 13.1 (12.88 English tons) and the weight carried on the rigid wheel base truck gives an average pressure on the track as high as 15 tons per running metre (4.5 English tons per foot). These loadings are extremely heavy for a 25 to 27 kgr. (50.4 to 54.4 lb. per yard) rail and ordinary sleeper spacing.

The weight distribution on the electric locomotives will be much more favourable. Axle loads are limited to 12 tons (11.8 English tons) and the average load on the track per metre within the rigid wheel base, will not exceed 12 tons (3.6 English tons per foot). The advantages of such weight reduction will mean considerably less maintenance cost in connection with the permanent way.

The total adhesion weight on the driving axles of the steam locomotives is 50 tons.

Such a design has meant that the rack portion has had to do an excessive amount

of work and pressures on the rack teeth and rack pinions have been high. With the electric locomotive the total weight on the adhesion driving axles will be about 72 tons and due to this, the efforts on the rack will be less than has been the case hitherto, in spite of the fact that the train weights hauled will be 150 tons instead of 110 to 120 tons as with steam.

Each locomotive will be equipped with six motors, four of which will be connected to the driving axles and two to the rack pinions. When running on adhesion sections the four adhesion motors will be connected in pairs across the 3 000 volt circuit and when so connected, will give an average schedule speed of about 30 to 35 km. (18.6 to 22 miles) per hour. When operating on the rack grades, the four adhesion motors will be connected in series across the 3 000 volt circuit and the two rack motors also in series across the 3 000 volt circuit. With this connection for the rack, the speed characteristics of the locomotive will give about 15/16 km. (9 to 10 miles) per hour for the schedule time assumed. This method of operation will enable the power requirements to propel a train over the line to be maintained at a fairly uniform figure.

All adhesion driving axles of individual trucks will be mechanically coupled and each rack motor is to be coupled to its individual rack pinion.

Adhesion and rack motors will in no way be tied together mechanically.

When motoring on the rack sections with normal setting of control, the tractive effort required will be equally divided between adhesion motors and rack motors. It will, however, be possible to alter the division of work between adhesion and rack motors to 10 % above and below this normal for continuous operation.

When running down grade, the motors will operate as generators and thus act as a braking medium.

The subject of braking has been given special attention, since it is recognised that this feature is an exceedingly important one on a line having the characteristics of the Transandine Railway.

The wagon stock is provided with Westinghouse straight and automatic braking equipment, double pipe lines being run for this purpose. The total pressure on the brake blocks is equivalent to 75 % of the total weight of the wagons. Each wagon is equipped with 6 and 8 inch cylinders, the smaller being used when wagons are empty (10 tons), the 8 inch when wagons are half loaded (20 tons) and both when fully loaded to 30 tons.

The electric locomotives will be provided with adequate equipment for :

1° *Air braking.* — Straight as well as automatic air brakes, for the adhesion wheels, to work independently of as well as in conjunction with the Westinghouse air brakes on the wagon stock. Straight air brakes only will be applied to the brake drum on the rack pinion shaft;

2° *Electric braking*, by the adhesion and rack motors;

3° *Powerful hand braking* operating through a screw, to be applied on the locomotive adhesion wheels, as well as rack drums.

The straight air brake equipment will be applied to the locomotive and train adhesion wheels for ordinary retardation, but may also be called upon to wholly control the speed of the train on any of the rack or adhesion down grades and likewise to assist the electric braking equip-

ment to hold the train at speed on any of the down grades.

The straight air brakes on the rack brake drum are intended to operate only in case of emergency.

Electric braking will be used to hold the train at speed on the down grades. On grades where the braking effort required to hold the train at speed exceeds the rated braking effort exerted by the motor equipment, straight air braking on the adhesion wheels of the locomotive and train will be applied to make up the difference.

The capacity of the air brake system applied to all the driving wheels of the locomotive, will give a total pressure on the combined brake blocks equivalent to 90 % of the weight of the locomotive.

In case the train should get out of control a down rack grade, an automatic speed limiting device adjustable for a speed of between 18 and 25 km. (between 11 and 15.5 miles) per hour will, in a positive and simple manner, cause a full automatic air application to be made on the adhesion wheels of the locomotive as well as the train. The speed control governor will be mechanically operated, driven positively from the rack pinion shafts.

Each locomotive will be equipped with two pantograph current collectors, individually raised by compressed air cylinders and lowered by gravity. A suitable hand operated air pump will be provided for raising the pantographs in case the normal air pressure fails.

[ 625 .142.2 & 691 ]

# A new wood treating process,

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Figs. 1 to 7, p. 2506 and 2514.

(*Railway Review.*)

The preservative effect of zinc chloride has been known for many years, and it has been used extensively in timber treatment, but this use has been decreasing in recent years for two reasons. Timber so treated, especially if used in hot, arid situations, is much given to checking and splitting. If used when there is an abundance of moisture the solubility of the zinc chloride causes it to leach out of the wood and its benefits are largely lost. To overcome both of these handicaps, and to prolong the preservative effect of the material, considerable investigation and experimental work along the lines of using zinc chloride with petroleum has been undertaken.

One of the drawbacks to the process heretofore tried out is that they all require double treatment, either with the zinc chloride followed, after a period of seasoning, with the oil, or, first with the oil and, without removing from the cylinders, then with the zinc chloride. The process which is described in the following paper, presented to the American Wood Preservers' Association at its 21st annual meeting, overcomes the objection of double treatment and the incidentally high cost of extra handling of the timber.

* * *

During the last twenty years considerable experimental work has been done in attempts to develop a wood treating process in which the well known preservative effect of zinc chloride should be prolonged by an additional treatment with petroleum or its products, such as crude fuel oils. These investigations have been stimulated by a growing recognition that a preservative treatment of wood, in addition to preventing decay, must act to minimize checking, splitting, brooming, and other manifestations of natural wear, or weathering of unprotected timbers.

Several combination treatments with zinc chloride and petroleum oils have been developed and used experimentally. These treatments have been carried out by a variety of methods, which will be summarized as follows :

1) Crossties were treated with zinc chloride solution, as in the usual Burnett process, seasoned, and finally treated with petroleum, either by an open tank or pressure process;

2) Crossties were first treated with crude oil by the Rueping empty cell process, then, without removing from the cylinder, treated with zinc chloride solution by the full cell process;

3) Crossties were treated by the Rueping empty cell process, using a more concentrated solution of zinc chloride than is ordinarily employed for the Burnett treatment. Then, without remov-

*Table 1.* — Pine ties analyzed from full cell treatments in Pittsburgh.

| Number of tie. | Concentration of emulsion at time of treatment in per cent $ZnCl_2$. | Weight before treatment in lb. | Weight after treatment in lb. | Gain in weight in lb. | Gain per cubic foot in lb. | Per cent of $ZnCl_2$ by calculation on assumption of even absorption. | Per cent $ZnCl_2$ by actual analysis. | Ratio $ZnCl_2$ by analysis to $ZnCl_2$ by calculation. |
|---|---|---|---|---|---|---|---|---|
| 2..... | 4.47 | 150.0 | 208.0 | 58.0 | 13.1 | 1.25 | 1.34 | 1.07 |
| 9..... | 4.32 | 125.5 | 190.5 | 65.0 | 24.0 | 1.47 | 1.40 | 0.96 |
| 15..... | 4.14 | 125.5 | 211.0 | 85.5 | 32.0 | 1.68 | 2.20 | 1.31 |
| 22..... | 3.91 | 193.0 | 225.5 | 32.5 | 7.9 | 0.61 | 0.84 | 1.37 |
| 25..... | 3.84 | 152.5 | 197.5 | 45.0 | 13.9 | 0.88 | 1.20 | 1.33 |
| 41..... | 3.74 | 151.0 | 217.0 | 66.0 | 20.5 | 1.13 | 1.37 | 1.21 |
| 42..... | 3.74 | 127.5 | 174.5 | 47.0 | 17.3 | 1.01 | 1.05 | 1.04 |
| | | | | | | | | Ave : 1.20 = (*a*) of formula 1. |

*Table 2.* — Analyses of emulsion during treatments at Pittsburgh.

| SAMPLE OF EMULSION. | Total amount of emulsion used when sample was taken. | Fraction of total emulsion used. | $ZnCl_2$ concentration by analysis. |
|---|---|---|---|
| 1. — At beginning . . . . . | 0 | 0 | 4.47 |
| 2. — After 1st treatment . . . . . | 80 | 0.073 | 4.38 |
| 3. — During 5th treatment . . . . . | 300 | 0.273 | 4.24 |
| 4. — During 9th treatment . . . . . | 840 | 0.763 | 4.13 |
| 5. — Before 15th treatment . . . . . | 1 300 | 1.18 | 3.77 |
| 6. — Before 17th treatment . . . . . | 1 350 | 1.23 | 3.78 |
| 7. — Before 24th treatment . . . . . | 1 740 | 1.58 | 3.74 |

ing from the cylinder, a subsequent treatment with petroleum was given by either the Rueping empty cell or the full cell process.

These processes are all subject, in greater or lesser degree, to one disadvantage, namely, that the time and manipulations required for treatment are the sums of those for two movements; that is, one with zinc chloride solution and the other with petroleum. Also, in the process involving seasoning between treatments, there are additional handling and storage costs.

The present process, worked out at Mellon Institute of Industrial Research of the University of Pittsburgh, is the result of investigations directed toward combining treatments with petroleum and zinc chloride in one movement.

### Theoretical considerations respecting the new process.

In the present development a mixed zinc chloride petroleum oil preservative is prepared by emulsification methods. It seems advisable, therefore, before describing the new process, to outline the theory of emulsification.

An emulsion may be defined as a mixture of two non-miscible liquids, in which one of them is evenly distributed or suspended in the other as small discrete particles. A certain degree of stability is assumed but it is not a well defined property. The distribution of one liquid in another is spoken of as dispersion; the finely divided particles are called the internal or disperse phase, and the surrounding liquid medium the external or continuous phase. In general, only those emulsions that contain a third substance in lesser quantity, referred to as an emulsifying agent or stabilizer, show any considerable degree of permanence.

A reliable test for the external phase is that the emulsion shall be readily miscible, without violent agitation, with an additional quantity of the liquid constituting that phase.

In the emulsification of oil and water or aqueous solutions two kinds of emulsions are possible, *viz.:* one in which the water constitutes the continuous phase and the other in which oil is the continuous phase. Products of the first type are called *oil-in-water* emulsions and are of the well known type of oil-water mixture. Where oil constitutes the external continuous phase, the mixture is spoken of as a *water-in-oil* emulsion.

*Oil-in-water* emulsions are characterized by a milky appearance and a limpidity approaching that of water, as the concentration of oil decreases. In general, they are stabilized by water dispersed colloids, such as alkali soaps, animal glue, casein, starch, dextrine, etc. Increasing concentration of oil causes a rapid increase in viscosity and sometimes a reversal of phase.

*Water-in-oil* emulsions have an oily or greasy appearance, depending on whether they are low or high in water content, and are miscible with an excess of oil and immiscible with water. They are stabilized by oil dispersable gums and colloidal substances, such as alkaline earth and heavy metal soaps, asphalt, rosin, etc.

For the treatment of timber with an emulsion there are certain basic requirements, the more important of which are as follows :

1) Both phases of the emulsion must penetrate into the timber; *i. e.,* the emulsion must be of such fineness and stability that the wood will not separate its phases by filtration;

2) The emulsion should be of such stability and consistency as to permit its use in commercial treating equipment;

3) It must be possible to so regulate the composition that a desirable ratio of the component preservatives can be obtained in the timber.

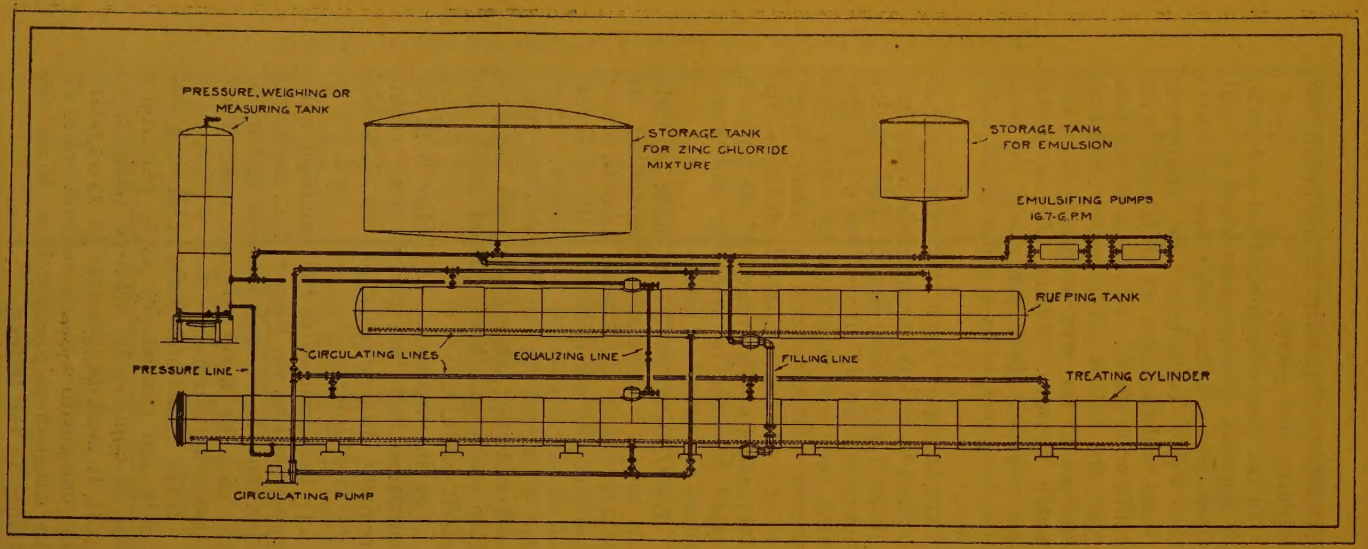


Fig. 1.

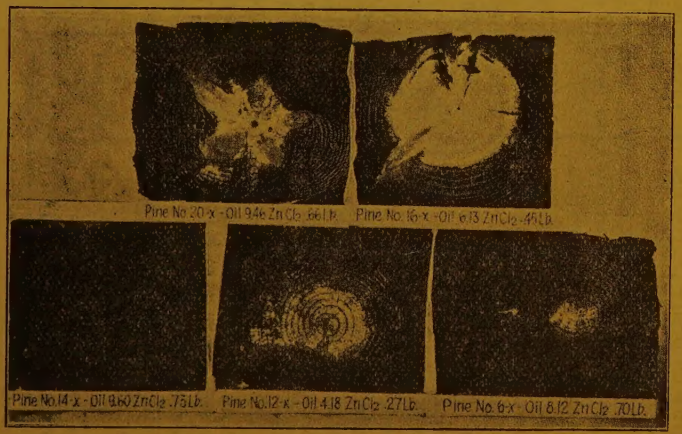
Pine No.20-x - Oil 9.46 ZnCl2 .66 Lb.
Pine No.16-x - Oil 6.13 ZnCl2 .49 Lb.
Pine No.14-x - Oil 9.60 ZnCl2 .75 Lb.
Pine No.12-x - Oil 4.18 ZnCl2 .27 Lb.
Pine No.6-x - Oil 8.12 ZnCl2 .70 Lb.

Fig. 2.

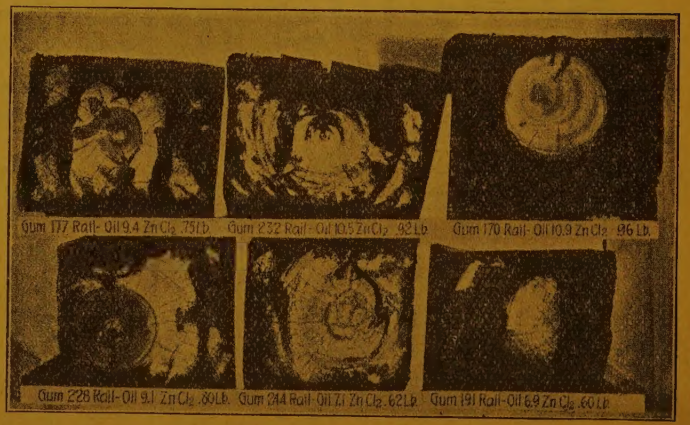
Gum 177 Rail - Oil 9.4 ZnCl2 .75 Lb.
Gum 232 Rail - Oil 10.5 ZnCl2 .92 Lb.
Gum 170 Rail - Oil 10.9 ZnCl2 .96 Lb.
Gum 228 Rail - Oil 9.1 ZnCl2 .80 Lb.
Gum 244 Rail - Oil 7.1 ZnCl2 .62 Lb.
Gum 191 Rail - Oil 6.9 ZnCl2 .60 Lb.

Fig. 3.

These requirements have been met satisfactorily by certain emulsions of zinc chloride solution in petroleum fuel oils. Penetration and distribution of zinc chloride and of oil have been verified by chemical and physical tests. It has also been found possible to vary the absorption of zinc chloride within limits above and below the values that experience with zinc treatments has fixed as optimum.

Stability has been demonstrated by continuous treatments under operating conditions in a two-tie experimental cylinder at Mellon Institute, and in a ten-tie cylinder at Somerville, Tex., in co-operation with the Santa Fe Tie & Lumber Preserving Company (1).

## Description of the process (2)

### *Preparation of the emulsion.*

Asphaltic residuum and distillate fuel oils are mixed in proportions to give a suitable viscosity, which may vary from 45 to 65 seconds Saybolt at 180° F. This mixture is agitated with from 15 to 25 % of a 10 to 40 % zinc chloride solution, then pumped under high pressure (about 2 000 lb. per square inch) and at a temperature of about 170° F., through an emulsifying valve. This valve so disperses the zinc chloride solution that an emulsion of sufficient fineness and stability for wood impregnation is obtained. The natural asphaltic and resinous constituents of suitable fuel oils have a protective or stabilizing action, and where these oils (3) are used the addition of an artificial stabilizer is unnecessary.

Such *water-in-oil* emulsions properly prepared, are quite stable. They do not, however, remain of uniform composition at treating temperatures, without some agitation. This property is readily explained by the fact that the dispersed particles of zinc chloride solution have a density from 1.2 to 1.6 times that of the dispersing oils.

The necessary agitation in the treating cylinders is obtained by the use of a circulating pump.

### *Conditions for treating timber with the emulsion.*

The usual procedures for pressure impregnation of timbers are applicable to the emulsion process. The operations of initial and final evacuation, steaming, and application of initial air have been employed for the customary purposes and with usual results. The mixture may be regarded as a petroleum made toxic by zinc chloride, and during treatment it acts like a petroleum of similar viscosity. Ordinary treating temperatures of 170° F. to 180° F. are employed. It is not advisable to operate above 185° F. for any appreciable period of time.

Figure 1 represents a treating cylinder, 74 inches in diameter by 132 feet long, ideally arranged for emulsion treatments. Regular equipment consisting of a treating cylinder, overhead Rueping cylinder, weighing or measuring tank, and storage tanks has been illustrated. The additions to this standard unit-cylinder equipment consist of a 1 000 gallons per minute circulating pump, two emulsifying pumps (one in reserve), with a combined capacity of 16.7 gallons per minute and an overhead storage tank for emulsion of 8 000 gallons capacity. The emulsion storage capacity is designed to enable more continuous operation of the emulsifying pump and to afford a reserve supply of emulsion for from three to four treatments where desired.

(1) These ties are to be installed in test sections of the Santa Fe lines in various climates.

(2) U. S. patent applied for.

(3) In experiments up to the present time the following residuum and crude petroleums have been found adaptable to the process : Residuums from heavy and light Mexican crudes, residuums from California crudes, California crude oil, and Caddo crude oil.

*Table 3.* — Pine ties analyzed from Somerville treatments.

| Number of tie. | Concentration of emulsion at treatment in per cent $ZnCl_2$. | Weight before treatment in lb. | Weight after treatment in lb. | Gain in weight in lb. | Gain per cubic foot. | Per cent of $ZnCl_2$ by calculation on assumption of even absorption. | Per cent of $ZnCl_2$ by actual analysis. | Ratio per cent $ZnCl_2$ by analysis to per cent by calculation. |
|---|---|---|---|---|---|---|---|---|
| 1 extra. . . | 4.40 | 116.0 | 153.5 | 37.5 | 12.50 | 1.070 | 1.85 | 1.73 |
| 6 — . . . | 3.90 | 103.0 | 133.5 | 30.5 | 10.17 | 0.891 | 1.91 | 2.14 |
| 8 — . . . | 3.80 | 119.5 | 155.0 | 35.5 | 11.83 | 0.870 | 1.54 | 1.77 |
| 10 — . . . | 3.65 | 108.0 | 129.0 | 21.0 | 6.52 | 0.594 | 1.12 | 1.88 |
| 12 — . . . | 3.55 | 108.0 | 123.5 | 15.5 | 5.22 | 0.446 | 0.72 | 1.61 |
| 14 — . . . | 3.45 | 122.0 | 158.0 | 36.0 | 12.00 | 0.785 | 1.36 | 1.74 |
| 16 — . . . | 3.35 | 94.0 | 114.0 | 23.0 | 7.67 | 0.676 | 1.00 | 1.48 |
| 18 — . . . | 3.27 | 108.0 | 148.0 | 40.0 | 12.94 | 0.884 | 1.94 | 2.19 |
| 20 — . . . | 3.20 | 112.0 | 150.0 | 38.0 | 11.83 | 0.810 | 1.78 | 2.22 |
| | | | | | Ave : 9.55 | | | Ave : 1.86 = (a) of equation 1. |

*Table 4.* — Analyses of emulsion during treatment of 200 pine ties at Somerville Texas.

| Number of treatment. | Fraction of total emulsion used (Total — 8500 lb.) | $ZnCl_2$ in emulsion by analysis. |
|---|---|---|
| | | Per cent. |
| 0. . . . | 0 | 4.41 |
| 8. . . . | 0.292 | 3.69 |
| 10. . . . | 0.364 | 3.89 |
| 12. . . . | 0.437 | 3.56 |
| 14. . . . | 0.510 | 3.37 |
| 16 . . . | 0.583 | 3.20 |

*Table 5.* — Calculating values for $(x)$ on varying $(m)$ when $(a) = 1.20$

| $1.2\,m$. | $m$. | $x$. |
|---|---|---|
| 0.00 | 0.00 | 4.47 |
| 0.100 | 0.083 | 4.399 |
| 0.300 | 0.250 | 4.277 |
| 0.700 | 0.417 | 4.177 |
| 0.500 | 0.585 | 4.094 |
| 1.00 | 0.833 | 3.999 |
| 1.30 | 1.082 | 3.928 |
| 1.80 | 1.500 | 3.800 |
| 2.00 | 1.666 | 3.786 |
| 3.00 | 2.500 | 3.762 |
| 5.00 | 4.165 | 3.729 |

*Table 6.* — Calculated values for $(x)$ on varying $(m)$ when $(a) = 1.86$.

| $am$. | $m$ | $x$. |
|---|---|---|
| 0.0 | 0.0 | 4.50 |
| 0.30 | 0.161 | 3.96 |
| 0.40 | 0.215 | 3.81 |
| 0.60 | 0.323 | 3.56 |
| 0.70 | 0.376 | 3.45 |
| 1.00 | 0.537 | 3.18 |
| 1.30 | 0.699 | 2.98 |
| 1.60 | 0.860 | 2.84 |
| 2.00 | 1.075 | 2.71 |
| 3.00 | 1.612 | 2.52 |
| 4.00 | 2.15 | 2.46 |
| 6.00 | 3.22 | 2.42 |

*Table 7.* — Analyses of emulsion during treatment of oak and gum ties.

| (1) Number of treatment. | (2) Species of wood. | (3) Per cent of $ZnCl_2$ in emulsion by analysis. | (4) Per cent of $ZnCl_2$ in emulsion used for replacement. | (5) Ratio of column 4 to column 3. |
|---|---|---|---|---|
| 0. | Oak. | 4.59 | 7.00 | 1.52 |
| 1. | — | 4.59 | 7.00 | 1.52 |
| 2. | — | 4.77 | 7.00 | 1.46 |
| 5. | — | 4.93 | 7.00 | 1.42 |
| 8. | — | 4.71 | 7.00 | 1.49 |
| 10. | — | 5.00 | 7 00 | 1.40 |
| 11. | Gum. | 4.83 | 7.00 | 1.45 |
| 13. | — | 4.93 | 7.00 | 1.42 |
| 15. | — | 5.12 | 7.00 | 1.37 |
| 18. | — | 4.95 | 7.00 | 1.41 |
| 21. | — | 5.36 | 7.00 | 1.33 |
| 25. | — | 5.37 | 7.00 | 1.33 |
| 27. | — | 5.52 | 7.00 | 1.27 |
| 34. | — | 5.95 | 7.00 | 1.18 |
| 35. | — | 5.96 | 7.00 | 1.18 |
| 36. | Oak. | 5.96 | 7.00 | 1.18 |
| 37. | — | 5.87 | 7.00 | 1.19 |
| 39. | — | 5.60 | 7.00 | 1.25 |
| 41. | — | 5.77 | 7.00 | 1.21 |
| 46. | — | 5.79 | 7.00 | 1.21 |
| 49. | — | 5.59 | 7.00 | 1.25 |
| 51. | — | 5.63 | 7.00 | 1.24 |

To facilitate control of the zinc chloride concentration, it is desirable not to have a large reserve of emulsified mixture. Obviously a large reserve is not necessary, because the emulsifying pumps may be of such capacity as to replenish the supply of emulsion during each charge. The storage of the zinc chloride solution and oil mixture, agitated and supplied to the emulsifying pumps as needed, may be of any desired capacity. Operation of the emulsifying pumps, therefore, serves the double purpose of stabilizing the mixture and transferring it to the treating unit.

### *Penetration and absorption of zinc chloride and oil.*

Penetration is plainly visible in timber treated by this emulsion process, because a water-in-oil dispersion has the general appearance and characteristics of the oil. Accompanying are illustrations from photographs showing the penetration obtained on hewn pine, gum

*Table 8.* — Zinc chloride content of oak and gum ties.

| Number of tie. | Per cent of $ZnCl_2$ calculated assuming even absorption. | Per cent of $ZnCl_2$ by analysis. | Ratio of excess absorption factor ($a$). |
|---|---|---|---|
| Oak 3-X | 0.535 | 0.587 | 1.09 |
| — 16-X | 0.559 | 0.673 | 1.20 |
| — 19-X | 0.499 | 0.618 | 1.24 |
| — 88 | 0.751 | 0.841 | 1.12 |
| — 200 | 0.645 | 0.750 | 1.16 |
| | | | Average : 1.17 |
| Gum 9 | 0.92 | 1.33 | 1.44 |
| — 21 | 0.81 | 1.04 | 1.33 |
| — 170 | 1.65 | 1.76 | 1.08 |
| — 177 | 1.39 | 1.12 | 0.80 |
| — 191 | 1.15 | 1.37 | 1.19 |
| — 232 | 1.56 | 1 68 | 1.08 |
| — 228 | 1.35 | 1.10 | 1.20 |
| — 244 | 0.95 | 1.05 | 1.10 |
| | | | Average : 1.18 |

*Table 9.* — Amount of original emulsion remaining after using a given quantity.

| Fraction of preservative used ($m$) of equation II. | Per cent of original mixture remaining ($y$, of equation II. | Number of treatments in a commercial cylinder to give the value to ($m$). |
|---|---|---|
| 0 | 100.0 | 0 |
| 0.10 | 90.5 | ... |
| 0.20 | 74.1 | 1.5 |
| 0.50 | 60.6 | 3.3 |
| 0.70 | 49.6 | 4.7 |
| 1.00 | 36.8 | 6.6 |
| 1.50 | 22.3 | 10.0 |
| 2.00 | 13 5 | 13.3 |
| 2.50 | 8.2 | 16.6 |
| 3.00 | 5.0 | 20.0 |
| 4.00 | 1.83 | 26.7 |
| 5.00 | 0.67 | 33.4 |
| 6.00 | 0.25 | 40.0 |

*Table 10.* — Amount of $ZnCl_2$ at various depths in emulsion treated ties.

| Number of ties in Somerville experiments. | $ZnCl_2$ in whole tie. | $ZnCl_2$ in rail section. | | | | $ZnCl_2$ in middle section. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total section. | Sample A. | Sample B. | Sample C. | Total section. | Sample A. | Sample B. | Sample C. |
| | Lb. per cubic foot. | | | | | | | | |
| Oak 16-X | 0.29 | ... | ... | ... | ... | 0.22 | 0.33 | 0.14 | ... |
| — 19-X | 0.32 | 0.38 | 0.45 | 0.28 | ... | ... | ... | ... | ... |
| — 88 | 0.50 | 0.57 | 0.62 | 0.50 | ... | ... | ... | ... | ... |
| Gum 170 | 1.00 | 1.03 | 1.86 | 1.13 | ... | ... | ... | ... | ... |
| — 191 | 0.60 | 0.93 | 1.52 | 0.58 | ... | ... | ... | ... | ... |
| Pine 12-X | ... | ... | ... | ... | ... | ... | 0.41 | 0.18 | ... |
| — 14-X | ... | ... | ... | ... | ... | 0.70 | 0.73 | 0.74 | 0.64 |

and red oak, treated in co-operation with the Atchison Topeka & Santa Fe Railway, at Somerville, Tex.

The hewn pine specimens shown in figure 2 were treated with a mixture of viscosity 61.8 seconds Saybolt at 180° F., and mixed to contain 4.5 % by weight of zinc chloride. The oil content was 80 % leaving 15.5 % of water.

The gum and oak ties shown in figures 3 and 4 were treated with a mixture of 7 % zinc chloride, 80 % petroleum, and 13 % water. Its viscosity at 180° F., was 64.7 seconds Saybolt.

The gum and oak sections were cut at the rail base, those of pine were cut from the middle of the ties. The figures for oil and zinc chloride under the respective sections are in pounds per cubic foot and are calculated from weights of the individual ties before and after treatment.

In every case a preferential or selective absorption of zinc chloride was indicated, both by the results of analyses of ties treated and by analyses of the emulsion used. (See tables 1, 3 and 8.) For example, if an emulsion containing 5 % of zinc chloride were used for a treatment giving a retention of 10 pounds per cubic foot, the zinc chloride absorbed would not be 5 % of 10 pounds or 0.5 pound, but some figure higher than this amount.

This excess absorption of zinc chloride is constant for a given kind of timber, and increases with an increase in difference between gross and net absorption. Whether or not it is directly proportional to this difference (kick back) has not been demonstrated conclusively.

The effect of this excess absorption of zinc chloride on an emulsion in continuous use is to decrease the concentration of zinc chloride in it. However, it is mathematically obvious that, treating with a given supply of emulsion, and replacing it as used with emulsion of the original concentration, an equilibrium

concentration of zinc chloride will result. Otherwise stated, the zinc chloride content will not drop below a certain definite concentration, which, when multiplied by a factor of excess absorption, will just equal the original concentration. At this equilibrium concentration the zinc chloride retained is equal to that which would be retained from the original mixture if absorption of the two phases were even.

The mathematical solution of this problem is of interest in determining the rate of change and resultant concentration of a mixture under given conditions.

The general equation of change is :

$$x = \frac{c}{a} + \frac{c(a-1)}{ac^{ma}} \quad \text{. . . (Eq. 1)}$$

where :

$x$ = the concentration of zinc chloride in the emulsion at any time.

$a$ = the factor of excess absorption of zinc chloride. This is a constant, depending upon the kind of timber and the treatment given. It is numerically the ratio of zinc chloride actually retained by the wood to that calculated by assuming absorption of zinc chloride and oil to be even.

$m$ = the fraction of the total quantity of emulsion in use that has been absorbed by the timber at a given time. Obviously, if a constant supply is maintained ($m$) will be equal also to the amount of emulsion added after starting treatments.

$c$ = the original concentration of zinc chloride in the emulsion and its concentration in the emulsion added for replacement.

The applicability of equation 1 is shown by figure 5 below. Curve I, figure 5 was calculated for some full cell treatments of pine, where $a$ was found to be 1.20 by actual analysis of ties. Curve II was calculated for Rueping empty cell treatments (10 pounds per cubic foot) of shortleaf pine at Somerville, Tex., for which $a$ was found to be 1.86. Curves $I_A$ and $II_A$ of figure 5 are taken from actual analyses of emulsion samples during the respective treatments.

The data from which calculated curves were obtained and plotted are presented in tables, 1, 3, 5 and 6. The data for experimental curves are given in tables 2 and 4. It is to be noted that $a$, or the excess absorption factor used in calculating curves of decrease in zinc chloride content, is determined from averages of actual analyses of treated ties. This factor may also be determined by dividing the original concentration by the equilibrium concentration, *i. e.*, the lowest average concentration reached in use. Tables 5 and 6 give values calculated for plotting theoretical curves I and II, respectively.

The observed agreement between actual curves for decrease in zinc concentration and calculated curves will be taken as evidence that an equilibrium is actually obtained. More conclusive proof is afforded by a series of treatments made on hardwoods (red oak and gum) at Somerville, Texas. It was decided to use a mixture carrying 7.0 % of zinc chloride. Experience up to that time indicated that the factor of excess absorption ($a$ of equation I) would not exceed 1.40. Dividing 7.0 by 1.40 gives 5.00 as the approximate equilibrium concentration to be expected. Anticipating this a mixture containing 5% of zinc chloride was prepared to start and replaced as used with 7.0 % mixture. That is to say, treatments were started with a zinc chloride concentration near the expected equilibrium. During the treatment of 500 oak and gum ties the mixture was analyzed from time to time and there was no drop in zinc concentration, but an increase showing that the original concentration (approximately 5 %) was below the equilibrium value,

The analyses of this mixture are tabu-

lated in table 7, and shown graphically as figure 6. It is evident that the equilibrium concentration is slightly higher for gum than for oak, and that the average value is about 5.80 %, corresponding to an excess absorption factor of $\frac{7}{5\ 80}$ or 1.21.

A number of the oak and gum ties were sampled and analyzed. From the average excess zinc chloride found the excess absorption factors were calculated. These values of $a$ were 1.17 for oak and 1.18 for gum. The agreement with the value for $a$ or 1.21, obtained from the observed equilibrium concentration of he mixture, is regarded as satisfactory. Table 8 gives the analytical data for the oak and gum ties sampled.

In connection with the question of stability of a wood treating emulsion in use, it is of interest to know how many treatments are required to use completely the initial charge. Operating under the conditions that a constant supply of emulsion is maintained by replenishing as used, the equation for calculating the amount of original mixture present, where

$y$ = amount of original emulsion present.
$m$ = fraction of total quantity in use that has been consumed, and
$e$ = base of the natural system of logarithms

is

$$y = \frac{1}{e^m} \quad \ldots\ldots\ldots \quad (2)$$

By assuming certain values for $m$ and calculating $y$, figures for table 9 were obtained. In the third column the number of treatments corresponding to the given values of $m$ are tabulated. It is assumed that a commercial cylinder used 15 % of the working mixture per treatment. This table shows that after 40 treatments, or about two weeks operation, the amount of original preservative present would be less than one quarter of one per cent. The calculations indicate, therefore, that under treating conditions there would not be present an appreciable quantity of emulsion over two weeks old. Emulsions have been used continuously at Pittsburgh and at Somerville for periods in excess of six weeks.

With some emulsions, particularly when used at temperature above 180° F., it is desirable to withdraw a small portion of the mixture from the bottom of the Rueping cylinder for re-emulsification. In this way water introduced from wet timber and distilled from the emulsion is removed. This fraction withdrawn several times per week need not be greater than 0.5 to 2 % of the total quantity in use. Calculations of emulsification cost shown herewith allow for 10 % re-emulsification.

A question of considerable importance in evaluating the emulsion process is the distribution of zinc chloride obtained. Is there a filtering action by the wood fiber resulting in a concentration of zinc chloride in the surface layers of the timber treated ? Data have been obtained showing that zinc chloride is adequately distributed in the oil-treated area. Qualitatively, the distribution of zinc chloride may be demonstrated by the potassium ferricyanide-potassium iodite-starch color test or by the ferricyanide-uranium acetate color test. The distribution of zinc chloride has been shown more conclusively by quantitative chemical analysis.

In figure 7 are pictures of rail or middle sections of oak, gum and pine ties treated at Somerville. These sections were cut into layers as indicated by white lines and numbered A, B and C toward the center. These layers were sampled separately and analyzed for zinc chloride. The amount of zinc chloride in the various layers is given in table 10. Comparison with the photograph shows that the zinc contents of

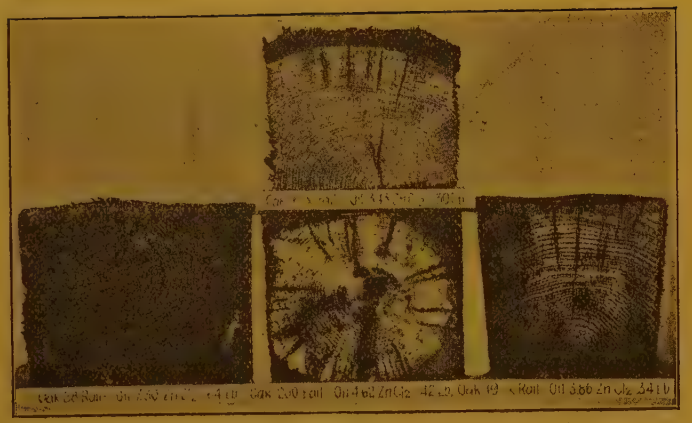

Fig. 4.

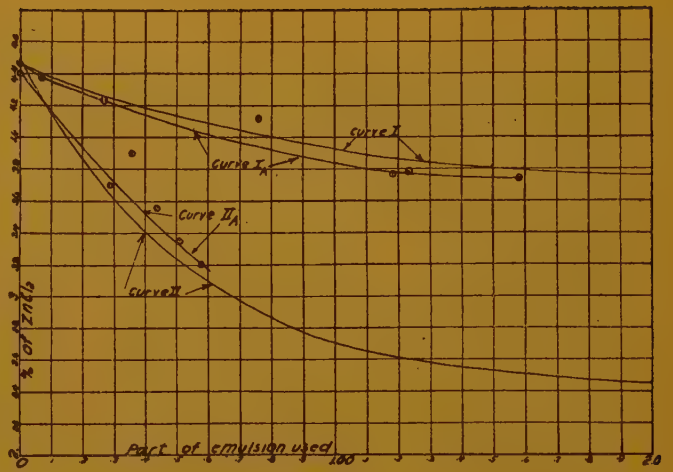


Fig. 5.

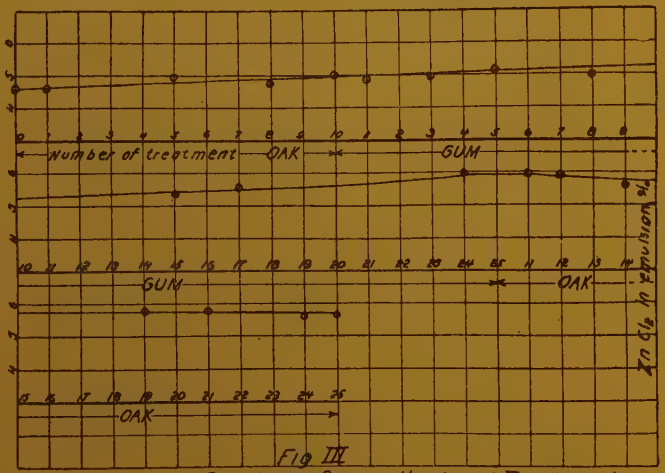


Fig. 6

Fig. 7.

the inner layers are certainly not less than proportional to the oil present.

**Cost data for emulsion treatments.**

For emulsion treating costs two factors must be added to the standard for treating plant operation. These factors are :

1) The cost of emulsification;
2) The cost of circulating in treating and Rueping cylinders.

These two costs have been calculated on the basis of cost per gallon and cost per cubic foot of timber.

*Emulsification cost per gallon of preservative.*

The cost of emulsifying is made up of power and of interest and depreciation on the investment in machinery. The power cost may be calculated as follows:

$$h.\,p. = \frac{0.000252\,(g.\,p.\,m.) \cdot h}{e}$$

where :

$h.\,p.$ = horse power required.
$h.$ = head in feet against which pump operates,
$g.\,p.\,m.$ = capacity of pump in gallons per minute, and
$e$ = the efficiency of the pump.

For an 8.33 gallons per minute pump, operating at 60 % efficiency, the horse power becomes :

$$h.\,p. = \frac{0.000252 \times 4\,600 \times 8.33}{0.60} = 16.3\ h.\,p.$$

On a basis of 34 pounds of steam per horse power-hour, 7 pounds of steam per pound of coal, and coal at $5.00 per short ton, the power cost per gallon may be calculated.

$$\frac{16.3 \times 34 \times 1 \times 5}{7 \cdot 500 \cdot 2\,000} = \$0.000396 \text{ per gallon.}$$

At 10 % re-emulsification, the power cost would be

0.000435 per gallon . . . . (1)

*Circulating cost per gallon of preservative.*

In a 74 inch diameter by 132 foot cylinder approximately 2 000 gallons of preservative are used per charge of timber. A 6-inch centrifugal pump of 1 000 gallons per minute capacity is sufficient for this cylinder. On a basis of 30 foot water head of frictional resistance, the horse power requirements of this pump are about 12. The maximum operating time of the pump per charge may be taken at 8 hours. Then, using prices for coal as before, the cost of circulating per gallon is calculated as follows :

$$\frac{12 \times 8}{2\,000} = 0.048 \text{ h. p.-hours}$$

per gallon of preservative.

$$\frac{0.048 \times 34 \times 5\,000}{7 \times 2\,000} = \$0.000582 \text{ per gallon.} \quad (2)$$

*Interest and depreciation on emulsifying and circulating equipment.*

The investment in machinery may be taken at $4 200. With interest at 6 % per annum and depreciation at 14 %, the per gallon cost on a basis of 6 000 gallons of preservative per cylinder per day is :

$$\frac{4\,200 \times 0.20}{365 \times 6\,000} = \$0.000384 \text{ per gallon.} \quad (3)$$

The total cost of emulsification per gallon obtained by adding items (1), (2) and (3) is :

$$0.000435 + 0.000582 + 0.000384 = \$0.00140$$

per gallon.

*Cost of zinc-petroleum mixture per cubic foot of timber.*

An average desirable treatment on the basis of present knowledge is 8 pounds of oil (about one gallon) and 1/2 pound of zinc chloride per cubic foot. With petroleum at 4 cents per gallon and zinc

chloride at 6 cents per pound the cubic foot cost of preservative is :

| | |
|---|---|
| $0.04000 | cost of oil. |
| 0.03000 | cost of zinc chloride. |
| 0.00175 | cost of power, interest, and depreciation (1 1/4 gallon of emulsion per cubic foot). |
| $0.07175 | total cost of emulsion per cubic foot of timber. |

Assuming that timber impregnated with zinc chloride and petroleum will be protected throughout its « mechanical life », it is evident that this process promises economies in treating costs.

## SUMMARY.

By employing an emulsion of zinc chloride solution in petroleum fuel oils, timbers have been impregnated satisfactorily with oil and zinc chloride in one movement.

No large tests have been made with oils requiring artificial emulsion stabilizers and only certain asphalt bearing residuum fuel oils, particularly Mexican and California base oils (1), have been found to give adequate natural stability to the emulsions.

A method of operation, including equipment required, has been worked out and some cost data assembled. No great changes from the usual conditions and processes of pressure impregnation have been employed, but the customary temperature of 180° F., cannot be greatly exceeded.

Semi-industrial treatments have been in progress at Somerville, Tex., for several months. This work is being done in co-operation with the Atchison Topeka & Santa Fe Railway and the Grasselli Chemical Co. It is anticipated that these treatments, involving 3 500 ties, and started during August 1924, will be nearing completion by 1 February 1925.

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[ 625 .242 (.73) & 691 (.73) ]

# The development of the reinforced concrete car,

By A. B. REEVE,

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Figs. 1 to 5, pp. 2519 and 2520.

(*Railway Age.*)

To limit one's conception of concrete to the usual heavy, brittle, rock-like material weighing 144 lb. per cubic foot such as is often used in heavy foundations, is to ignore both the basis of thought behind the development of the reinforced concrete railroad car and the revolutionary progress which in general has been made in concretes for special uses. These developments in new concretes not only open the field to light weight construction, but offer increased resiliency and other physical properties entirely in keeping with the necessities of the case, to say nothing of manifold advantages over the usual materials of car construction.

In order to give a clear conception of the fundamental ideas underlying the application of reinforced concrete to car

(1) No extensive tests of various crude and residuum petroleum oils have been made but it is planned to make such an investigation in the near future.

construction, let the reader picture to himself an ordinary composite gondola car, for example, having trussed steel frames on the sides, with the usual vertical and diagonal members, sheathed all around on the inside with wood planking protecting the steel somewhat from the contents. Let him now picture the following transformation : the side trusses gradually shrinking into a mere network of light steel mesh, and the wood sheathing becoming workable like poured concrete, and surrounding the steel mesh and then gradually hardening into a strong impervious special concrete with the steel embedded in its center. The result is the reinforced concrete car. The steel frame is still there to take the heavy stresses, but it has been reduced to the form of a net-work of steel. The steel net-work is inside the concrete and is thus given real protection, not only from the car contents but from the elements. The great disadvantage of the tendency of steel to deteriorate is thus overcome. The concrete itself becomes the sheathing and the steel is inside the sheathing. Assuming that the concrete used is not only resilient and suitable as sheathing, but also fire-proof and durable, which wood is not, and that the whole transformation is practicable and economical, we then catch a glimpse of the fundamental thoughts underlying the reinforced concrete car, and some of its advantages.

### Progress of the development

The development of the reinforced concrete car originated with Joseph B. Strauss, consulting engineer and president of the Strauss Bascule Bridge Company, Chicago, and dates back to the year 1907.

The basis of the original thought on the subject was the unsatisfactory nature of the materials then in use, namely, steel and wood or a combination of the two, and the belief that more satisfactory materials as regards strength, durability, cost, etc., were needed. Patents were issued in 1909.

A few years later the world war with its extraordinary demands on both the steel industry and transportation facilities looked as if it would force the use of other materials than steel and wood in car construction. Foreign countries even began extending reinforced concrete construction to barges and small ships. Later the United States Shipping Board, faced with a desperate situation in regard to the scarcity of materials suitable for the construction of sea-going ships, finally turned to reinforced concrete. Mr. Strauss' initial patents of ten years previous embraced the use of this material in railroad car construction and thus under war pressure, plans were rushed through for the construction of the first reinforced concrete railroad car ever built.

The original concrete demonstration car was described on page 776 of the 21 March 1919, *Railway Age* (1).

This car took the form of a solid bottom gondola. There were no precedents to go by, no scientific basis for calculations or design. What was not known had to be guessed at. The idea was ridiculed, and the material and construction situation was almost hopeless. Nevertheless, despite upsets and difficulties without number, the car was finally completed by February, 1919.

### Details of original demonstration car.

| | |
|---|---|
| Completed and placed on rails | February 15, 1919. |
| Type | Solid bottom gondola. |
| Capacity (load) | 50 tons. |
| Capacity (volumetric) | 1 800 cubic feet. |
| Width of body (outside) | 9 ft 8 in. |
| Length of body (outside) | 41 ft 6 1/2 in. |
| Height of body (inside) | 4 ft 8 in. |

This car came about as near being an all-reinforced-concrete car as it was pos-

(1) See also *Bulletin of the International Railway Congress*, No. 9, July-August-September 1919, p. 161.

sible to make it. Ordinary rod reinforcing was used, and even the cross-bearers were of reinforced concrete. The center sills and bolsters, however, were of steel. The body was of concrete, edged with steel, and reinforced with diagonal and longitudinal rods of various sizes from 3/16 inch to 3/8 inch in diameter, spaced from 4 inches to 8 inches on centers. Inside stakes were used, integral with the body walls. The floor was of concrete reinforced with rods. The concrete used weighed about 16 % less than ordinary sand and gravel concrete, the finished weight of the car being 53 600 lb.

### Performance of original demonstration car.

In some quarters the car was received with much scepticism and doubt. One engineer, when the use of this car in coal service was under discussion, expressed the opinion that he thought it might do for soft-coal service, provided the coal was *very soft.* Another insisted that the car would not last 30 days, and after it had survived this period of service, generously extended its lease of life to 90 days. This was over 6 years ago and this same car is still in service. On the other hand, it must in justice be said that the development enjoyed the confidence, encouragement and support of a great many others from its very inception.

After completion, the car was given a preliminary tryout of 30 days in the yards about Chicago, after which it was dedicated and placed for 30 days of test service in the coal carrying trade. After this it was loaded with steel rails and put through its second 30-day test period of service under the direction of the United States Railroad Administration. On 17 June 1919, it reached Washington, D. C., after a total service of over 5 000 miles in 90 days, during which time it carried full cargoes of coal, steel rails and billets, experienced every variety of railroad service, bulk loading, clam shell and car dumper unloading, and endured every test of use and abuse; including side swiping, collision test, etc.

It was then inspected by the United States Railroad Administration and the Bureau of Standards at Washington, after which it was again placed in service, this time in the coal and iron trade.

This extensive usage, crowding the equivalent of almost a year's service into a few months, clearly demonstrated the soundness of the underlying principles on which the car was based and laid a firm foundation for further successful development.

A record of the tests of this car include the following :

*Collision test.* — No damage to the concrete car; the composite car struck was damaged.

*Impact test.* — 4 400-lb. clam-shell bucket dropped 18 to 20 feet, and the blow repeated many times. The concrete on the under side of the floor cracked where the bucket fell. It was patched on spot by ordinary methods in a short time. Engineers witnessing this test expressed the opinion that similar treatment would have severely damaged or even destroyed a wood or steel floor.

*End wall test.* — Steel rails sliding forward, one rail went through one end of the car making a hole in the concrete but leaving the reinforcement intact. It was patched on spot by ordinary methods in a short time. Belief was again expressed that the damage was slight in comparison with that which wood or steel would have shown.

*Billet and rail loading test.* — Billets and rails were loaded by the usual methods, being dropped into the car from varying heights. No effect was detected.

*Clam-shell unloading test.* — Two of the internal stakes on one side of the car, and the transverse rib on the end were abraded from the blow of a 4 400-lb. clam-shell bucket. These were not repaired, the damage being slight. Con-

Fig. 1. — Interior view of original demonstration car, taken at the time of cement gun repairs following six years' service.

Fig. 2. — Old steel car in process of conversion to concrete. Plates removed, reinforcing attached.

Fig. 3. — Interior view of old steel car after conversion. Doors shown are temporary wooden doors.

Fig. 4. — Exterior of the original demonstration car which was built in 1919.

sidering that the ribs are wholly inside the car, the damage done was less than expected.

*Car unloader test.* — The car was passed through an unloader with a full load; it was tilted back with one-half load and unloaded. This was repeated three times, and no effect detected.

*Distortion test.* — The car was jacked up at one end 12 inches and no effect detected.

*Service test.*— In addition to the above the car passed through all the heavy duty service of 90-days' constant operation over various roads, and reached Washington in exactly the same condition, except for the patches noted, as when it started its career. Its lines were unchanged, its ends were still square and the concrete was smooth and intact as shown by the report of the Bureau of Standards. The car was not designed for either clam-shell unloading or for the car dumper unloading above noted. Considering this and conditions under which it was constructed and the fact that it was accidentally built with a kink in the top chords (inducing secondary stresses not intended or provided for) the record of this initial performance is certainly remarkable.

### Original demonstration car served its purpose.

The demonstration car, as was to be expected, was not perfect. For example, the floor design was somewhat light and the same applied to the ends. After five years of use the floor and ends were allowed to get into rather bad shape, affording in 1924 the opportunity of seeing what could be done with repairs. These

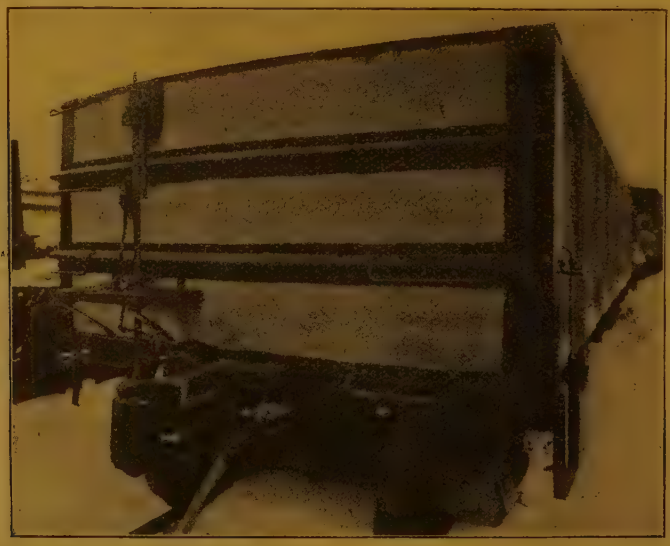

Fig. 5. — Close-up end view of 50-ton reinforced concrete gondola built in 1924.

repairs were effected without difficulty, portions of the floor, ends, and even the internal stakes, being restored by the use of a cement gun practically without the aid of form work. Figure 1 shows an interior view of this car as repaired.

Other technical points which demanded alteration might be mentioned; for

example, the internal stakes, which it was decided to try out first as one of several alternate designs because of better appearance.

In addition to this, the car was excessive in weight. This was due partly to the use of heavy concrete cross bearers, for example, and partly to the concrete mixture used at that time.

The important thing to realize is that all these difficulties are matters of detail which have been largely overcome by proper design and studies of what is actually required. One thing is certain : if the demonstration car had never been built, we would not now be discussing fine points of design of reinforced concrete railroad cars. We would still be wondering if such cars are possible.

Thus the demonstration car has served its purpose, and accomplished its mission. Its contributions to the development of the reinforced concrete railroad car include the following :

1. — It represented the first actual construction of a reinforced concrete car.

2. — It furnished something tangible to criticise, correct and build upon.

3. — It proved the practicability of the underlying idea of the reinforced concrete car.

4. — It proved that such a car would not « shatter to pieces », just as concrete ships proved this point.

5. — It pointed out many advantages which can be realized in getting away from wood and steel construction.

6. — It laid the groundwork for the technology of reinforced concrete car design and construction.

7. — It represented the first step toward overcoming the prejudice against the novelty of the idea.

8. — In the very changes it showed were necessary, it pointed the way toward technical progress.

9. — It stimulated the development of light weight concrete and indicated the requirements of the other physical properties of a correct material.

10. — It has permitted full advantage to be taken of the knowledge gained from thorough tests in service.

### Conversion of wood and steel cars to concrete.

In order to test out the feasibility of converting cars with worn-out bodies to cars with new reinforced concrete bodies, and in general to further the development, conversion plans were worked for several types of cars.

The process of conversion as it was applied to two steel cars in 1924 may be briefly described as follows. The cars as received were worn out, all-steel gondolas, drop bottom type, of 50 tons capacity each. They were both badly deteriorated. The plates were rusted to the point where a hammer could be driven through them in spots, the chord angles were bent and damaged and the ends distorted. The cross bearers were bent out of shape and their cover plates were in a hopeless condition. The drop doors had been bolted shut with planks and the cars had apparently been used as solid bottom cars for some time.

The old steel bodies were first removed, except the original stakes were left intact. The underframe was straightened, and the worn out cover plates were altered in keeping with the conversion plans. A new light steel body frame was then added to form an edging for the concrete. Old parts which could be salvaged were used in this new framework. The reinforcing was attached to the frame and the concrete finally applied. The conversion contract did not cover the drop doors and these were simply rebuilt temporarily with heavy wooden planking to keep down expense.

Unfortunately the light weight concrete desired was not available in time for use in these cars, and as the tracks on which they were being built had to be torn up by a certain date it was found necessary to use the only aggregate at hand, which was even heavier than that

used in the original demonstration car. This, coupled with certain test features which it was desired to add to these cars, resulted in considerable excess weight. Even then they weighed about two tons less apiece than the original demonstration car.

**Further aspects of the development.**

In order to test out further points of design, especially the employment of outside stakes, a gondola car was designed and built in 1924, of the same general dimensions as the original demonstration car, namely, length of body outside 41 ft. 6 in. width of body outside 9 ft. 8 in. and height of body inside 4 ft. 8 in. Although the stakes were on the outside they were made by an inward panelling of the sides so that there is no projection beyond the steel edging of the concrete.

It is beyond the scope of this paper to discuss the details of the design in this case, but it may be said that the very conservative proportion of light weight concrete introduced in this car brought the weight, while the concrete was still green, to 44 500 lb. corresponding to a cured weight of about 44 000 lb. In as much as the use of light weight material throughout would represent a substantial reduction in weight even over this figure, there is no reason to doubt that the development offers no disadvantage and even some possible improvement in the matter of car weight.

Although the only cars built so far have been gondola cars, plans for extending the development to box cars and other types of freight cars are under way and there seems no reason why this type of construction cannot be applied to passenger cars.

There would, of course, be no point in carrying on a development which merely aimed at doing « something different. » In the last analysis an industrial development must rest on the *benefits* to be derived from the changes which it involves. In this connection let it be said that the expectations of the founders seem more than justified.

For example, the present status of the development indicates the possibility of a substantial saving in the first cost of cars built of reinforced concrete over those built of the usual materials. Moreover, economical steel and wood construction have been pushed to the limit, whereas there is every opportunity of working out still more economical production methods with reinforced concrete than those now considered.

Reinforced concrete construction offers many of the advantages of both wood and steel without their disadvantages. It overcomes the difficulty represented by the liability of steel to deteriorate. Good insulating properties can be insured by proper concrete mixtures. The concrete itself is fire-proof and it protects the steel as in modern fire-proof building construction. Moreover, it lends itself to large construction and heavy loads, which wood does not.

Other advantages might be briefly mentioned. It reduces dependence on the steel market to a minimum, it is ideal for coal, slag, cinders and hot ashes; car interiors are free from projecting rivet heads and exposed metal; cars can be built of it with drop doors, drop ends, etc., for any class of service; it is adaptable to any of the existing standards; it requires a minimum of plant layout to construct and to repair. It thus offers an opportunity not only to reduce the heavy capital expenditures for rolling stock, which the railroads are faced with making in carrying out their program for adequate transportation facilities, but also to reduce the enormous current expenditures which the railroads now find it necessary to make for car maintenance and repairs.

[ 625 .245 (.45) ]

# Methods employed by the Italian State Railways for testing locomotive performances,

By Alessandro MASCINI and Guido CORBELLINI,
ENGINEERS IN THE LOCOMOTIVE DEPARTMENT OF THE ITALIAN STATE RAILWAYS.

Figs. 1 to 12, pp. 2526 to 2549.

(Taken from the *Rivista tecnica delle ferrovie italiane.*)

**Introduction by Luigi GREPPI, Engineer,**
Member of the Editing Committee of the *Rivista tecnica delle ferrovie italiane.*

Among the number of locomotives of all types exhibited by European and American builders in the splendid collection of railway rolling stock to be seen at the Vincennes Park during the Paris Exhibition of 1900, engine 3701 of the Southern Italian Railway Company, which operates the line along the Adriatic, was noteworthy on account of its originality, and received a large amount of attention from those visiting the Exhibition.

Built in the workshops of the above mentioned Company, this engine was the first of a series of forty-three which are still in service under the denomination of class 670 F. S. (originally class 370, and class 500 R. A.) and marked a bold and important step in the evolution of the steam locomotive in Italy. The construction of a boiler with the firebox carried over a bogie was such as to provide a very great increase in the dimensions of the firebox and was a novelty, which, in addition to the no less original arrangement of the cylinders — two high pressure cylinders on the left and two low pressure cylinders on the right, with crossover steam ports and cranks at 180° — gave rise to great interest among locomotive engineers of all countries.

Engineers of the Western Railway Company of France asked and obtained permission to try this engine on the line from Paris to Havre, and the *Revue générale des chemins de fer* published the results of trials made with the Western Railway's dynamometer car, which gave information on the characteristics of this

engine, namely, very high power, free running qualities, and high efficiency (1).

The engineers of the Adriatic Company naturally wished to carry out a more extensive series of tests in Italy where, however, they only had at their disposal for carrying out these tests, some chronometers by which one could determine the running times between certain points, some auxiliary devices whereby one could rapidly read at definite intervals the ordinary apparatus carried in the engine cab, and a few indicators of an obsolete type.

During a conversation which took place at Vincennes on engine 3701 R. A., one of our engineers asked Mr. Baudry, the Chief Locomotive Engineer of the Paris-Lyons-Mediterranean Railway, whether that Company would lend to the Adriatic Company its dynamometer car for a few months.

Mr. Baudry kindly consented, and it was with this dynamometer car that there were carried out in Italy, from March to January 1910, the first series of complete tests dealing with the running and tractive effort required to work trains, and on the resistance of rolling stock. This first series of Italian dynamometer tests formed the basis of the very valuable series of researches and investigations which were drawn up in a report published by the Adriatic Company in 1902. The observations and conclusions made were of use in solving important structural details, and those responsible for designing our locomotives made good use of these, especially as regards types 360 R. A. (subsequently 600 F. S.), 680 F. S. and 470 F. S.

Such was the commencement of dynamometer tests carried out in Italy. The utility of results obtained experimentally soon showed themselves to be so great that the Adriatic Company decided to design and construct a dynamometer car for its own use, which, being completed in the latter days of the operation of the system as a private company, was taken over by the State Administration and was used in 1906-1907 for a fuller and more complete series of tests which were carried out mainly on new types of steam locomotives for the State railways, and for the early tests of electric locomotives. This series of tests was followed by numerous others.

However, the equipment of the dynamometer car was gradually added to, and the technical and practical experimental methods, which were far from simple, were gradually improved and rendered more accurate, with the object of obtaining a good series of accurate and comparable results, always in view.

One of the elements of success which was invariably observed was to entrust the operation of the apparatus to the same staff, which are few in number, and to let this staff organise and carry out the tests. It is very seldom that there are any changes in the staff, and when one does occur it is always preceded by prolonged periods of working together between the old operator and his successor in such a way as to establish a strong tradition in

(1) See *Revue générale des chemins de fer*, 1901, second half year, pp. 411 to 438 : « Compound engine No. 3701 of the South Italian Railway Company (Adriatic Railway). Comparative trials with compound engines belonging to the Western Railway Company of France », by Mr. E. Decourt.

accuracy and method in the way in which the tests are carried out.

On several occasions, reports have been published containing a large number of results of the tests which have been carried out; however, these publications do not fully satisfy the requirements of engineers who wish to obtain a knowledge of the whole of the apparatus put at the disposal of our experimenters for carrying out running tests as they are conducted at the present time, and who wish also to have a complete account of the methods and conditions of observation and research under which the results have been obtained and drawn up. These methods and conditions are the result of long experience and of constant and close attention to detail.

This need has been met by the article which is now published, the authors being two young experimenters belonging to the State Railway Administration, who at the present time are engaged, with others, on this work.

We have no doubt that, despite its length and the inevitable descriptive character of the greater part of this article, it will be received as a veritable *vade mecum* by those who carry out experiments on locomotives, and is an excellent guide to be kept in the library among books of general reference for railway engineers.

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## METHODS OF CARRYING OUT THE TESTS.

### The dynamometer car.

For the satisfactory study of the locomotive itself and of all the numerous motive power problems which occur in railway operation, it is of the greatest importance to obtain experimental data dealing mainly with the power developed by a locomotive to haul a train at a given speed, that is to say, to overcome resistance and to attain a given kinetic energy.

It is advisable, in order that experimental data may be completely comparable with actual service results, that they should be obtained while the engine is working under conditions which are strictly the same as those met with in normal working, and for this reason the measuring instruments are as a rule placed in a special vehicle, the dynamometer car, which is marshalled between the engine and the train and forms part of the latter (1).

(1) The experimental data obtained in this way with a dynamometer car applies always to certain trains working over certain lines and do not therefore represent theoretical laboratory conditions. On the other hand, certain railway administrations approach the problem in a different manner and obtain results as to the power and fuel consumption of the engine under test conditions on a suitable test plant, the engine being stationary, neglecting thereby practical service conditions (such for example as the experimental plant at Altoona, Pa., United States, for engines of the Pennsylvania Railroad Company). Under these conditions experimental data is of a theoretical nature and can only be used for comparative tests of locomotives working under the same conditions, but are not comparable with engines working under actual service conditions where the engine is hauling a train. (See *Railway and Locomotive Engineering*, March 1923, pp. 72 to 74 : « Origin and development of the Pennsylvania Railroad Testing Laboratory-Its Establishment under direction of Theodore V. Eley », by Geo. L. Fowler.)

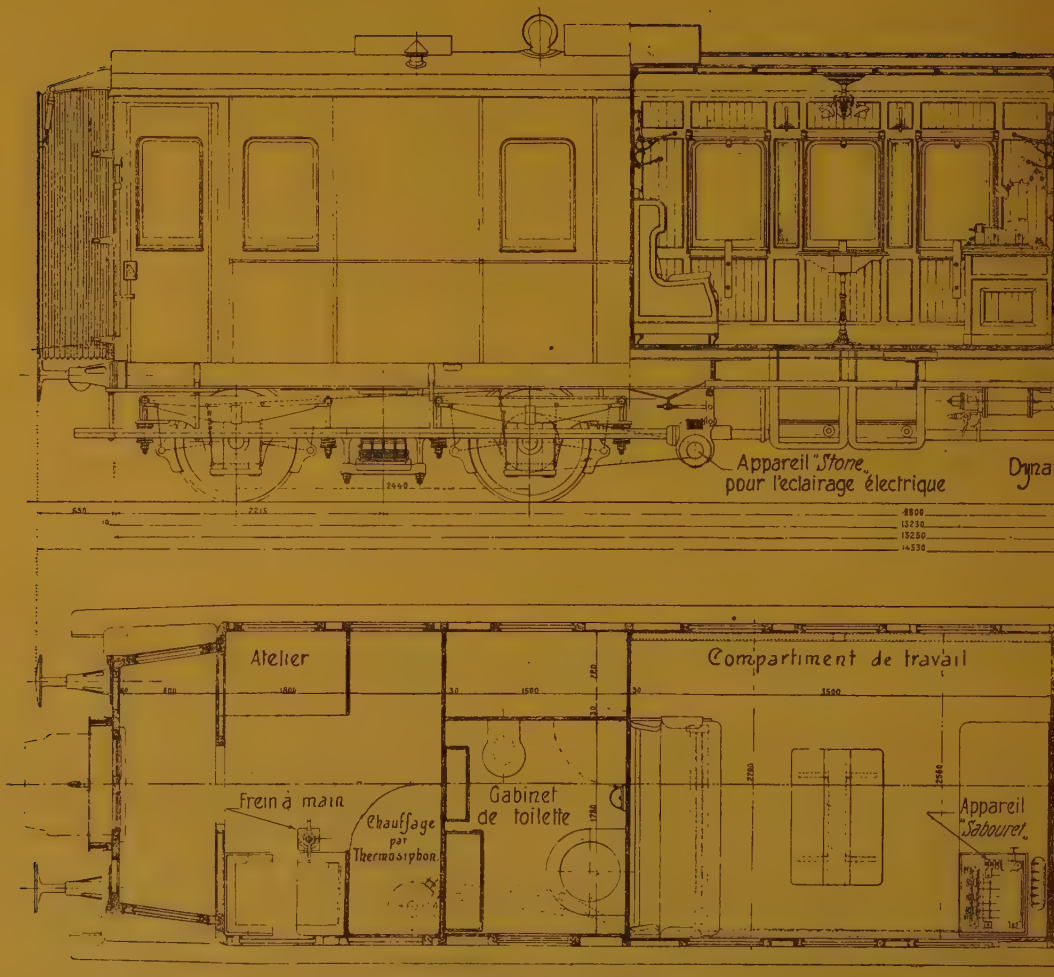
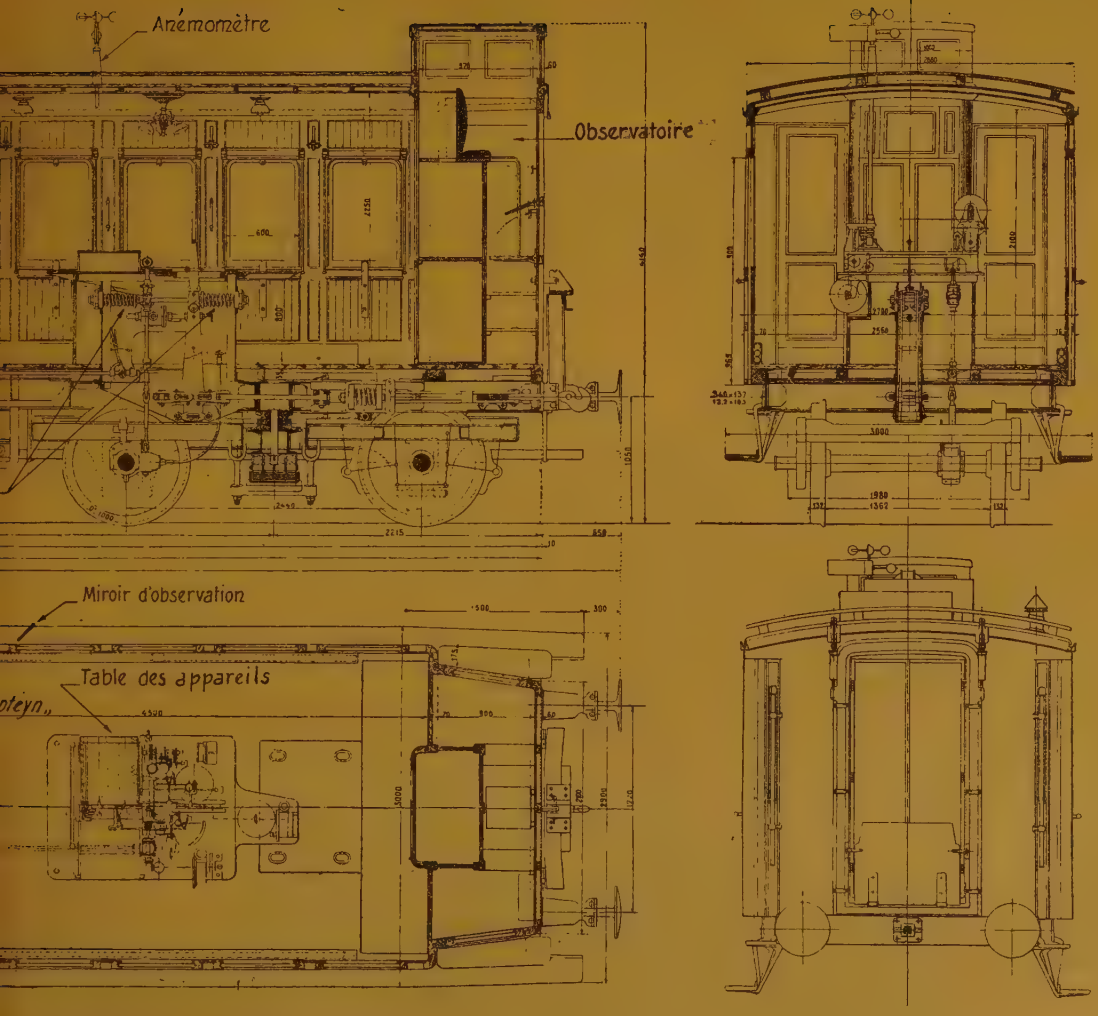



Fig. 1. — Dynam

*Explan*

| | | |
|---|---|---|
| Anémomètre | = | Anemometer. |
| Observatoire | = | Raised seat for observer. |
| Appareil « Stone » pour l'éclairage électrique | = | Stone's electric lighting appa |
| Dynamomètre | = | Dynamometer. |
| Miroir d'observation | = | Observation mirror. |
| Atelier | = | Work bench. |
| Frein à main | = | Hand brake. |




Italian State Railways.

*rench terms :*

Chauffage par thermosiphon . . . . . = Heating apparatus.
Cabinet de toilette . . . . . = Lavatory.
Compartiment de travail . . . . . = Office compartment.
Appareil « Kapteyn » . . . . . = « Kapteyn » apparatus.
Table des appareils . . . . . = Instrument table.
Appareil « Sabouret » . . . . . = » Sabouret » apparatus.

As is the case on certain large foreign railways, the Italian State Railways possess a dynamometer car (VADI $\frac{CR}{dz}$ 801 000) which formerly belonged to the Company working the Adriatic Railway, and which was constructed by the Locomotive Department in 1904 at the Florence workshops.

By means of this dynamometer car, which is fitted with various instruments, the Italian State Railways have carried out a large number of tests on the hauling capacities of the principal types of engines constructed in Italy which have been designed by the State Railways since 1905 up to the present date.

The chief results of these tests have been published by the General Direction of the State Railways (1).

The vehicle (fig. 1) is a bogie coach having a length of 13 m. 25 (43 ft. 6 in.) over head stocks (excluding the buffers). The width of the body is limited to 2 m. 70 (8 ft. 10 in.) so as to allow room for two vertical mirrors to be attached on either side, these being inclined at an angle of 45° to the longitudinal axis of the vehicle so that the operator sitting at the instrument table may see the road on either side and observe the stations, kilometre posts, and other features along the wayside. The construction of the underframe which carries the dynamometer is very rigid, the same being true of the springing arrangements, so that the vehicle runs steadily at high speeds.

The total weight of the vehicle is 31 t. 32 (30.82 English tons). It is divided into two principal parts : in the front portion are placed the instruments (figs. 2 and 3); the rear portion containing a small compartment with two tables for working out diagrams, seating accommodation, a lavatory and accommodation for the staff. At the two ends of the vehicle are two vestibules, the foremost one with an outlook window for communicating if necessary with the footplate staff, while the rear end is fitted with corridor communication leading to the train.

The car is lighted by electricity; the current for lighting and for all the apparatus being furnished by three batteries of accumulators which are automatically charged when running by a dynamo which is driven by a belt from a pulley keyed on the leading axle of the rear bogie (1).

Current from the same source is also used for operating all the electrical instruments with which the car is fitted.

A double system of heating is installed, namely, steam heating on the Haag system, and by a stove and hot water pipes.

Finally, the vehicle is fitted with a rapid acting Westinghouse brake acting on all wheels except those which drive the recording apparatus, and also with a hand brake acting only on the rear bogie.

The instruments with which the Italian State Railways' dynamometer car is fitted may be divided into several groups, namely :

1° The dynamometer;

2° The Doyen ergometer (2);

These instruments are mounted on a table shown in figure 4;

3° Instruments for investigating the action of the compressed air brake;

(1) See note (1), page 86, of the *Rivista tecnica delle ferrovie italiane*, XIIth year, vol. XXIV, Nos. 3-4, 1923.

(1) The apparatus, which is on Stone's system with accumulators, is of the type in general use on the Italian State Railways. (See the *Génie civil*, second half year 1922, No. 1, p. 13; No. 2, p. 36; No. 3, p. 59.)

(2) See the *Bulletin of the Railway Congress*, March 1909, p. 169 : « The inertia ergometer of Joseph Doyen and the resulting dynamometrical methods », by A. Huberti and J. Doyen; and the same periodical, February 1911 : « The Belgian method of testing locomotives while running », by J. Doyen.

Fig. 2. — Dynamometer car, Italian State Railways : View of instrument compartment.

Fig. 3. — Dynamometer car, Italian State Railways : Instrument table showing ergometer.

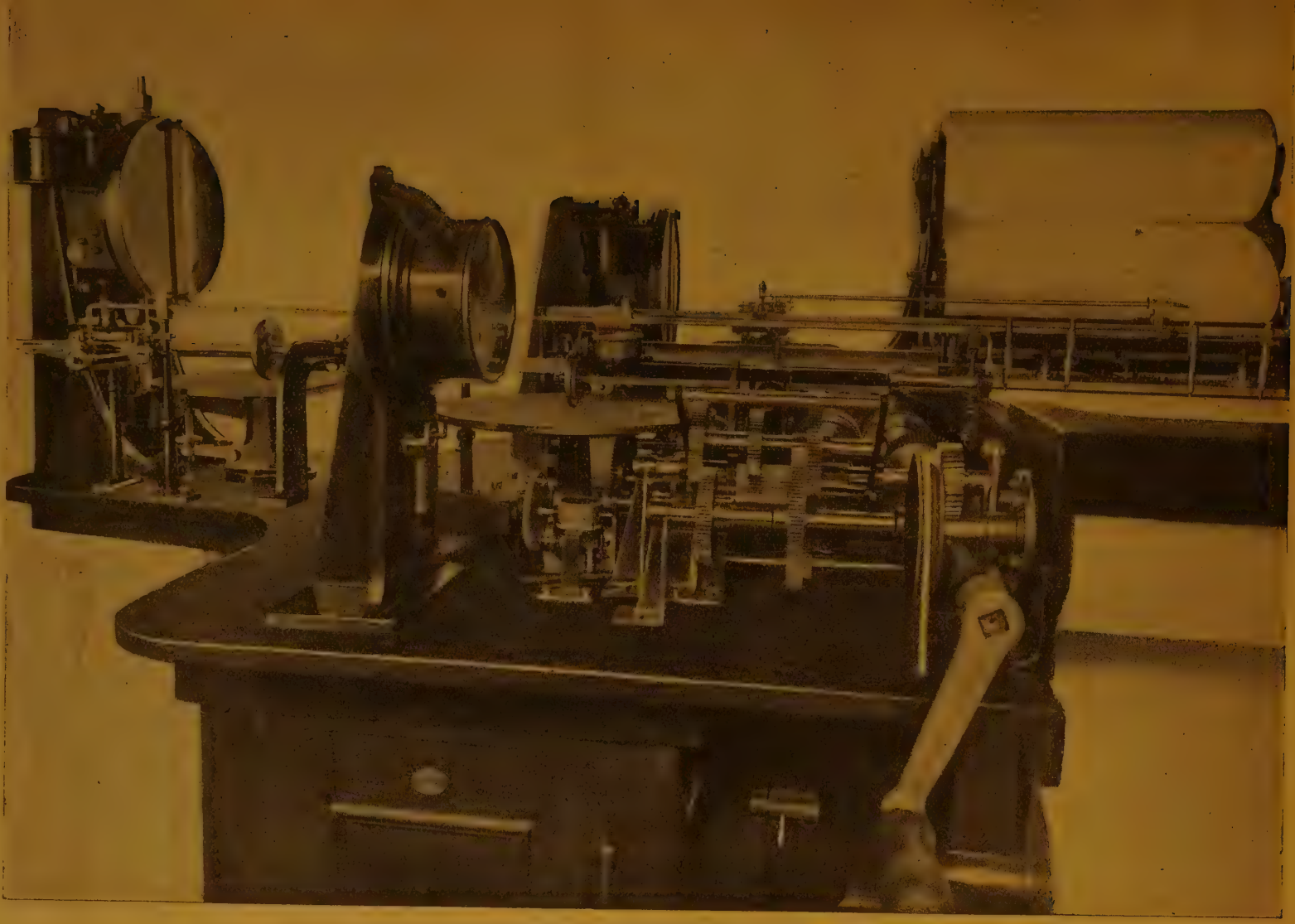


Fig. 4. — Dynamometer car, Italian State Railways : Instrument table.

4° Instruments for investigating the condition of the track and relative movements of the different parts of engines or vehicles, invented by Mr. Sabouret of the French Western Railway (1);

5° Instruments for registering the way in which the engine is fired and worked;

6° Instruments for testing electric locomotives.

The principal parts of the dynamometer apparatus were constructed by Messrs. Amsler-Laffon & Sons of Schaffhouse, and is similar to those which were already in use on the French Eastern Railway.

The instruments comprise the following :

*a*) The dynamometer apparatus itself;

*b*) The driving gear of the recording apparatus;

*c*) An indicator and recorder of the work done;

*d*) Speed indicators and recorders of the Amsler (2) and Hasler types;

*e*) A power indicator;

*f*) An anemometer.

One of the speed recorders (the Hasler instrument), the power indicator and anemometer were added subsequently; the anemometer was constructed by Messrs. Amsler, while the ergometer was constructed in 1910 by Messrs. Grieten of Brussels.

The whole of the apparatus mentioned above was described in detail in the September-October number 1923 of the *Rivista tecnica delle ferrovie italiane*. For brevity we will only describe here the dynamometer itself and the power indicator, which is an interesting application made by the Italian State Railways of the Hasler speed recorder, and of integrators of the disc type so as to obtain directly the value of the power developed at the drawbar, this being recorded on two paper ribbons, one of which moves proportionally to the time and the other proportionally to the distance travelled.

*a*) THE DYNAMOMETER. — This device measures and makes a continuous record of the tractive force exerted on the drawbar or the compressive force exerted upon the buffers. To clearly describe the operation of this device, we will refer to figure 5. In this case, as in all dynamometers, the intensity of the force in question is measured by the deformation of a spring which has been carefully calibrated, the spring M serving to measure tractive forces, while spring M′ measures the compressive force exerted on the buffers. The main lever A of the dynamometer is constructed, for the greater part of its length, of two heavy parallel iron plates, between the lower ends of which are firmly fitted three cross pieces of hardened steel of which two sides form a knife edge. The piece B constitutes the fulcrum of the lever which is rigidly fixed by the frame F which is bolted to the underframe. The knife edges E and E′ form the points on the lever at which are transmitted the tractive and compressive forces respectively by means of the links T and C. Finally, the washers H and I, which are also connected to the lever, bear against the springs M and M′ which they compress against the fixed points L and O. The amount by which each of these springs is compressed measures separately the tractive or compressive forces,

(1) The author has given a complete description of his apparatus in an article published in 1904. (See the *Revue générale des chemins de fer*, 27th year, 1st half year, No. 2, 1904, pp. 65 to 82 : « Investigation of the secondary movements of vehicles in motion », by Mr. SABOURET, Chief Engineer of the French Western Railway.

(2) A similar arrangement is used in the dynamometer car recently constructed for the Swiss railways. (See : « The Swiss dynamometer car », in the *International Railway Association Bulletin*, September number 1920, p. 604, and *Revue générale des chemins de fer*, for 1920, second half year, p. 821.)

and this is recorded on the paper of the recording apparatus.

It is interesting to follow the way the tractive or compressive forces are transmitted to the links T and C by a very simple mechanism.

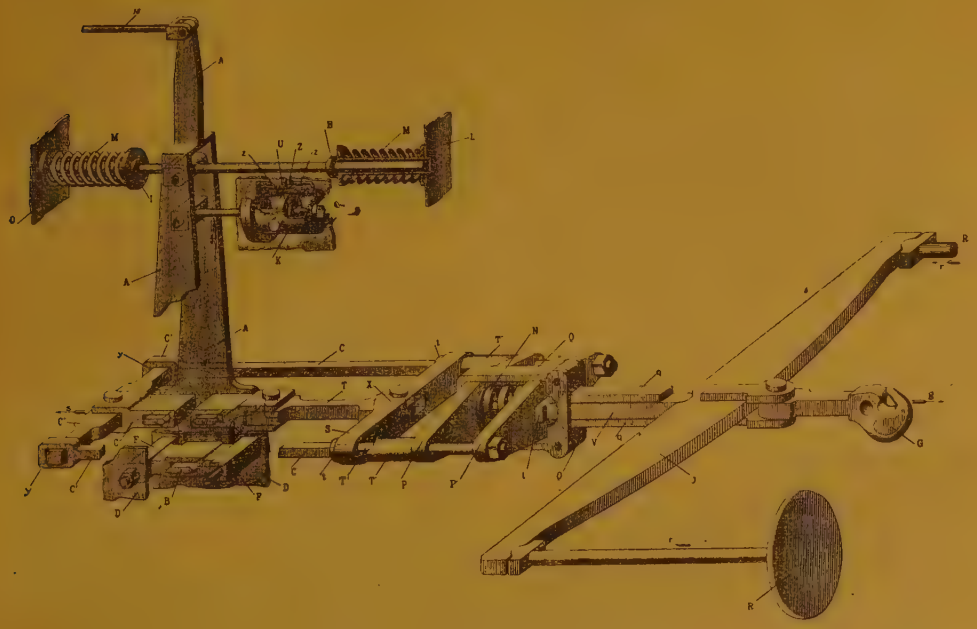


Fig. 5. — Diagram of dynamometer.

When the engine exerts a tractive effort in the direction of the arrow *g* on the drawbar G, the frame Q, which is rigidly attached to the drawbar by links *q* moves in the same direction, the plate P compressing the spring N, and consequently causing the plate P to move in the same direction by the action of the said spring. It should be noted that the spring N merely acts as an elastic intermediary between the engine and the dynamometer; in other words, it fills the part of the spring which is connected to the drawbar of ordinary vehicles and at the same time replaces, as we shall see later, the buffing springs, which are not fitted in this case as they are in the case of ordinary vehicles.

The movement of the plate P′ is transmitted in its entirety by means of the links T′ to the cross beam S, which, by means of a central link T, displaces the knife edge E, which gives lever A an inclined position in a forward direction, thereby compressing the spring M until the reaction of the latter re-establishes equilibrium in the system. In this way the deformation of the spring M is proportional to the intensity of the tractive effort exerted on the drawbar.

If, on the other hand, the engine is exerting a force in the opposite direction upon the buffers R, this is transmitted through the cross beam J to rectangular bar V, which, by means of the stops *i*, forces the plate P′ in the same direction, compressing the spring N, which, in turn, by means of the plate P, the

sleeves T″, the rods C′, the cross beams C″ and the links C, exerts a pressure on the knife edge E′ in the direction of the arrow *s*, and consequently inclines the lever A of the dynamometer to the rear, compressing the spring M′ until the reaction of the latter restores equilibrium.

At the joint X, between the pivot and its housing, sufficient play is provided to allow a cross beam S to remain free and not to compress the rod T when the dynamometer is subjected to buffing forces. In the same way play is allowed at Y between the rods C′ and the pins at the end of the cross beam C″, which allows the latter to remain free and not to compress C when the dynamometer is subjected to a tractive effort on the drawbar.

For reasons of simplicity of description, we have not given the details of the construction of the apparatus. It may be merely stated that all the rods or links and moving parts are guided and carried by rollers with the object of reducing frictional resistance to a minimum, so that if the springs M and M′ are taken out, the whole of the mechanism can be moved with the greatest ease, this being necessary in order to obtain a sensitive apparatus and to give accurate results.

Means are, of course, provided to rigidly fix the cross beam S to the underframe of the vehicle by means of two heavy iron cotters. In this case the dynamometer is not moved either by tractive or compressive forces, because the sleeve T′ absolutely prevents any movement of the plate P in the direction in which they tend to move under buffing forces.

Under these conditions the forces exerted at the drawbar G are transmitted to the frame of the vehicle elastically through the intermediary of spring N.

The force which is exerted at the drawbar G (or that which acts on the buffer R) does not have in practice a constant value, for besides the variations due to the increase or diminution of the drawbar tractive effort of the locomotive, there are the frequent and periodical variations caused by the wheels passing over the joints of rails, or by inequalities in the track in general, and especially by the variations in the tractive effort of the locomotive due principally to the uneven turning moment and by the impossibility of completely balancing the inertia of the reciprocating parts in the case of steam locomotives. Variations of the former kind, as well as those of the latter, are completely transmitted through the springs N and M (or M′) to the main lever A of the dynamometer, which therefore is subjected to two kinds of displacements: the true displacement which allows a record to be made of the variations in the drawbar pull of the engine, and the other, which is not required and which is to be as far as possible avoided, which consists of vibrations on both sides of the mean position of the lever A corresponding to the effective tractive effort exerted on the drawbar. The result is that the diagram traced by the pen, which is connected to the upper end of the lever A of the dynamometer, draws on the paper a constantly oscillating line, and the curve of effective tractive effort on the drawbar is the mean of this series of oscillations which are drawn out by the pen.

In the case of some locomotives or at certain speeds, the amplitude of the oscillations may become excessive, so that it is necessary to damp these so as not to affect the proper working of the other apparatus (the work integrator and the power indicator). For this reason, there is applied to the main lever A a damping device which consists essentially of the cylinder K which is completely closed, in which may move a piston U, which divides the cylinder into two separate parts, which are filled with glycerine. By opening the valve Z, one

may put the two ends of the cylinder into communication by the two ports *z* which are drilled in the body of the cylinder, and which are also filled with glycerine.

As the cylinder K is fixed to the underframe of the vehicle and the piston U is connected to the main lever A, it is obvious that if the valve Z is completely closed, glycerine cannot pass from one end of the cylinder to the other, and the piston is unable to move on account of the practical incompressibility of the fluid, and consequently remains immovable, thus fixing the lever A, whatever may be the tractive or buffing forces acting on the dynamometer, and consequently this does not move, just in the same way as when, as explained above, the cross beam S is fixed by means of cotters to the framework of the vehicle. It may also clearly be seen that suitably opening the valve Z allows the glycerine to circulate from one end of the cylinder to the other, thus allowing the piston U to move and follow the movements of lever A, provided it overcomes the resistance set up by the fluid in its passage through the restricted orifice of the valve Z.

By sufficiently reducing the free area of the said passage of the valve, one may make this resistance as high as is desired for *rapid movements*, such as those set up by vibrations of the lever A, whereas slow displacements due to a variation in the tractive effort are not affected. In this way it is possible to reduce the amplitude of the oscillations of the dynamometer diagram without altering its true form.

From the description given above of the dynamometer, it will be seen that it works perfectly correctly which ever way the vehicle is turned, whether this (as is done when possible) is in the direction in which the train is running, that is to say, the drawbar G is attached to the tender of the locomotive, or when the car is turned in the opposite way. In any case the function of the two springs of the dynamometer remains the same, for spring M is always the one which registers the tractive forces, and M′ the buffing forces.

It must not be overlooked that in the first case the forces measured are those exerted at the tender drawbar, that is to say, they include the tractive effort required for the vehicle itself which becomes an integral part of the train, while in the latter case the forces measured are those exerted at the rear drawbar of the dynamometer car, and consequently its weight is not included as part of the train, so that the force necessary to haul it is not included.

*b*) THE POWER INDICATOR was put in by the Italian State Railways after the instrument table was constructed; it indicates and records constantly the horsepower developed by the locomotive at the drawbar. This result is obtained by means of a combination of two instruments : a work integrator and a Hasler speed indicator of the type commonly used on locomotives.

In other words, in the same way as in a speed recorder one obtains the speed as a function of the distance run in a given time, so one obtains the power developed by a similar apparatus which indicates the work done in a given time.

The vertical driving shaft which is driven from an axle on the vehicle, drives an horizontal table 77, which turns at a speed proportional to that of the vehicle (figs. 6 and 7).

This table must turn in the same direction which ever way the dynamometer car is turned relative to the running direction of the train, and the driving shaft is connected to the main shaft of the dynamometer, which turns in either direction, and it is therefore necessary to fit on shaft 76, the two bevel wheels 75*a* and 75*b* which are mounted loose upon the shaft, but which carry on their inner side two dogs which engage with

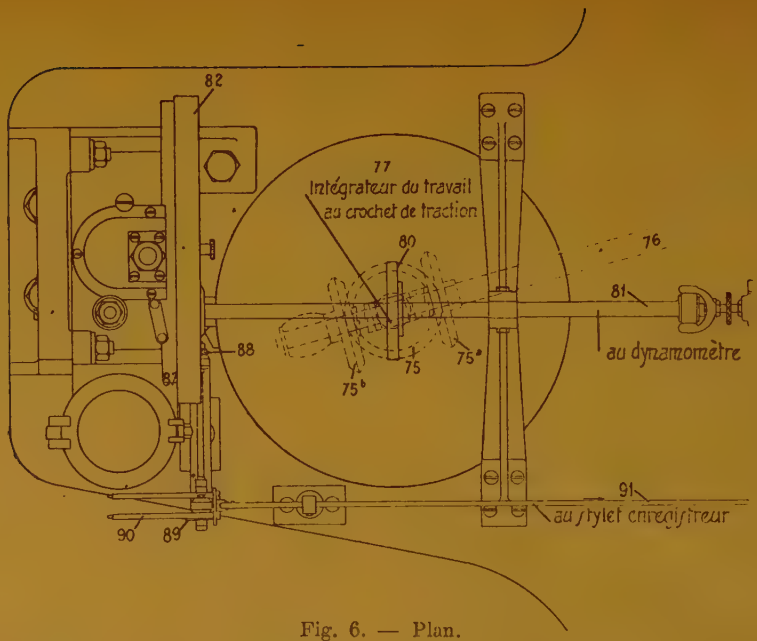



Fig. 6. — Plan.

*Explanation of French terms* : Intégrateur du travail au crochet de traction = Integrator disc. Au dynamomètre = To dynamometer. — Au stylet enregistreur = To recording pen.

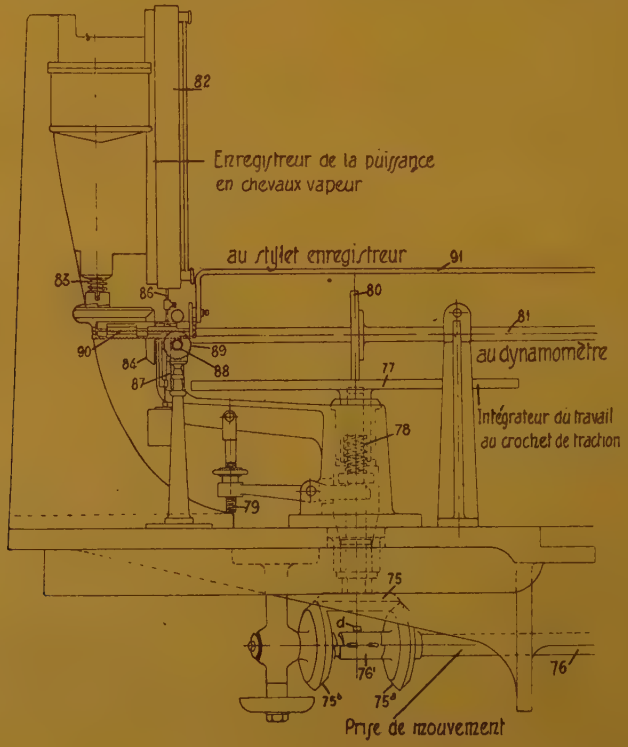



Fig. 7. — Elevation.

*Explanation of French terms* : Enregistreur de la puissance en chevaux-vapeur = Horse-power recorder. — Au stylet enregistreur = To recording pen. — Au dynamomètre = To dynamometer. — Intégrateur du travail au crochet de traction = Integrator disc. — Prise de mouvement = Driving shaft.

**Figs. 6 and 7. — Arrangement of work integrator.**

corresponding dogs cut on the sleeve 76′; the latter may slide longitudinally on the shaft, but is prevented from turning on it by means of a feather, and can in consequence be made to engage with the dogs on either of the bevel wheels 75*a* and 75*b*.

By means of the arrangement of the dogs on the sleeve 76′, which may be fixed by means of a set screw *d* in one or other of its extreme positions, one may arrange that the table 77 always turns in the same direction, being driven by one or the other of the two bevel wheels 75*a* and 75*b*, of which only one is rendered solid with the shaft by means of the dogs.

The table 77 is held by means of spring 78 (of which the tension may be regulated by means of screw 79) against the integrator wheel 80 which is driven by friction by the table whenever its point of contact on the table does not coincide with the centre of the latter. Wheel 80 is carried on the shaft 81, which is connected, by means of a Cardan joint which allows it to rotate, to a point on the main lever A of the dynamometer, so that it obeys all the movements of the latter, being displaced to one side or the other of the centre axis of the table along its longitudinal diameter, that is to say, parallel to the axis of the vehicle. It will thus be seen that the number of turns made by wheel 80, multiplied by a constant, gives the work developed, and we should have a direct measure of the power by determining the work done in a unit of time, that is by finding the number of turns of the wheel in the unit of time, that is to say, the speed at which the wheel rotates.

This speed is determined by a Hasler speed recorder of the usual type 82, which records it on a paper which moves as function of the time, consequently the speed curve of the rotation of wheel 80, that is to say, a curve giving the power developed by the engine at the drawbar is drawn directly on the paper ribbon.

It is not possible, for obvious constructional reasons, to stop the wheel 80 from rotating when buffing forces are transmitted to the dynamometer car, that is, when the point of contact of the wheel with the table is on the other side of the centre of the latter. As in this case, the direction of rotation of wheel 80 is reversed, while the vertical shaft 83 of the speed recorder should remain the same, the bevel wheel which gears with wheel 84 on the shaft 81 is not keyed on shaft 83 but runs loose upon the same, its boss being fitted with dogs which engage with corresponding dogs on a sleeve keyed to the shaft which is pressed against the same by a spring so that the shaft rotates in one direction only, while in the other direction it remains stationary while the sleeve compresses the spring and allows the teeth to disengage.

In this case therefore the speed of the rotation of the disc, or in other words, the power developed by a negative drawbar pull is not registered on the apparatus.

The Hasler instrument also records on the paper ribbon the distance run, and makes a mark at each half kilometre, that is to say, after a definite number of turns made by the wheel of the locomotive which drives vertical shaft 83 of the speed recorder. The meaning of these marks on the ribbon of the power indicator, *i. e.*, the speed recorder employed as an indicator and recorder of the power developed, may be easily realised, because the mark is made after a definite number of turns of the wheel 80 which produces the movement by the vehicle shaft 83, which represents the work developed at the drawbar of the locomotive, consequently the space between two points on the record represents, to some certain scale, a definite quantity of work developed by the locomotive.

The record of the power is thus recorded on the large continuous paper ribbon, and thus gives a curve of power plotted on a distance basis.

**Measuring devices on the engine.**

For tests with steam locomotives, the essential instruments used by the Italian State Railway Administration are the following :

1° Cylinder indicators (1); Crosby (1900), Rosenkranz (1904), Majlak (1910), all being provided with a drum for taking continuous indicator cards;

2° Amsler polar planimeters (2);

3° Apparatus for determining the dryness of the steam (3) of the Peabody type, modified by Max Innes, and of the Rateau type;

4° Pressure gauges, pyrometers, vacuum gauges and recorders (1).

These instruments are employed whenever necessary, in accordance with the methods explained in the following paragraph.

## METHODS OF CARRYING OUT THE TESTS.

We shall only deal here with the methods adopted for carrying out running tests on steam locomotives, as tests of this kind constitute the most important and most frequent use of the dynamometer car. We shall not include other special tests (brakes, movement of any portion of vehicles when running, electric locomotives. etc.), because it is evident that for any special test the special apparatus carried in the dynamometer car are used in accordance with methods which are suitable for the particular case, adhering however to the same fundamental principles of accuracy and method to which we shall allude in the following article.

With the means at the disposal of the Italian State Railways, one can carry out all the dynamometer tests necessary to make a complete investigation of the performance and fuel consumption of locomotives.

We will briefly indicate the methods which are always used in carrying out these tests in order to obtain all the factors which may be useful in throwing greater light upon the data recorded, and will then state, for each of these, the maximum probable error which may be

(1) See the *Technique moderne*, No. 12, of the 15 December 1912 : « Development of power indication. » Up to the present optical indicators have not been used because of their complicated construction and because of the considerable modifications which have to be made in reading the diagrams which prevent them being practical for use on locomotives. (See *The Engineer*, 26 January 1923, pp. 100 to 102 : « Micro-indicator for high speed engines. »

(2) See *Praktische Anleitung zum Gebrauch und zur gründlichen Prüfung des Polar-Planimeters* (*Practical instruction in the use and verification of polar planimeters*), Zurich, 1891. — V. Reina, *Geometria pratica*, p. 227. — *General theory, description, use and operation of planimeters and their practical results*, by G. Coradi. Zurich, 1904.

(3) See *Revue de mécanique*, 1911, p. 38, etc. : « Economic production of power : determination of the wetness of steam », by Mr. Izart. — *Teoria delle macchine motrici industriali*, by E. Garuffa. Vallardi, 1915. — *Il laboratorio sperimentale*, Naval construction at the Royal Arsenal at Spezia, by C. A. Bertella, Engineer, 1916. — *Trattato di macchine termiche* (Treaty on heat engines), by C. Baulino, Engineer, vol. I. Giusti, Livourne, 1921. — *Quantity of water in wet steam*. Béranger, Paris.

(1) See the *Industria* : « La tecnica del controllo della combustione allo stato presente » (Modern technical aspect of the control of combustion), vol. XXXVI, No. 5-6, March-April 1923. — *The Engineer*, 27 April 1923, pp. 437 to 439 : « The control of boilers by temperature and draught measurements », by I. Kershaw.

introduced in the figures by reason of the different degree of accuracy of the apparatus used.

### I. — Actual methods used during a test and calibration of the apparatus.

In all tests carried out on the line, the dynamometer car with its apparatus is used.

The tractive effort at the drawbar of the engine is therefore recorded and may be utilised for any calculation for which it is required. However, in addition to this, supplementary information is obtained on the locomotive by means of the instruments with which it is fitted, and of these we will give the following brief résumé :

a) *Taking indicator cards.* — In the case of the steam locomotives which are tested, as a rule indicators are fitted to the cylinders so that cards can be taken.

In any case, care should be taken that the pipes connecting the indicator to the two ends of the cylinders should have a sufficiently large internal diameter (12 mm. [1/2 inch]) and should be as short as possible, avoiding any difference in the length of the two pipes and ensuring that these should be free from sharp bends. In spite of the moderate length of these pipes and the lagging with which they are always covered, care should be taken that the quantity of water carried over by the steam is as small as possible, so that the final re-evaporation during expansion, with the corresponding alteration to the curve during this phase, seldom produce any appreciable effect.

However, this cannot always be avoided, and for this reason the operator is provided with all means for rejecting diagrams which show a defect of this kind. A further reason for making the two steam pipes leading to the indicator as short as possible and mounting the latter centrally between the front and rear covers, is that in this way one avoids, during admission and expansion, vibrations which are sometimes set up in the apparatus and which affect the cards (1).

As a general rule, cards are taken from the two ends of the cylinder successively with as little delay as possible between taking diagrams (2 to 3 seconds). Before taking each card, one should take care to open the drain cocks of the cylinders for a few moments, especially in the case of saturated engines, this being with the object of eliminating as far as possible water of condensation.

One should make careful choice of the moment at which the card is to be taken, so that during the short interval occupied by this operation, there should be no appreciable variation in the running conditions. The locomotive should not be passing round a curve, so that there may be no appreciable inequality in the work of the cylinders, and finally, it is necessary that conditions both as regards the boiler pressure and the position of the regulator and reversing lever should be kept as constant as possible.

To signal the instant at which the indicator card is taken, one as a rule proceeds in the following manner :

One or two operators, according to the type of locomotive, placed at the front end of the engine and suitably protected by a wooden cab, take the indicator cards. The engineer in charge of the tests in the engine cab notifies the operators the moment at which they should prepare to take a card. He uses for this purpose a horn fitted at the front end of the engine and attached to the end of a flexible metallic tube which is carried along the boiler and terminates at the other end in the cab with an indiarubber bulb. When everything is ready, the

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(1) See Robert Garbe : *Die Dampflokomotiven der Gegenwart* (Modern steam locomotives), 1920 edition, pp. 577 to 613.

operators reply by means of a speaking tube. A third signal given from the engine cab gives the word for the card to be taken, this being done immediately, while one of the operators, by means of an electric button, makes a mark on the paper record of the dynamometer car, which determines exactly the point on the road at which the diagram has been taken.

For each diagram, notes are made in the engine cab, on a suitable printed form, of the following information :

1° the exact time at which the diagram is taken; this is at the same time marked as a check on the ribbon of the dynamometer car opposite the mark which is made as described above;

2° the pressure in the boiler, and also in the case of compound engines, in the receiver. In simple superheater engines, the pressure in the header is noted in addition to that in the boiler;

3° the amount of regulator opening;

4° the cut-off in the high pressure and low pressure cylinders, as determined by the position of the reversing screw;

5° the vacuum in the smokebox, in millimetres of water;

6° the speed given on the engine speed recorder as a check on that given on the dynamometer card;

7° the temperature of the steam in the header in the case of superheater engines;

8° the temperature of the steam in the receiver in the case of compound superheater engines;

9° the temperature of the exhaust steam in the case of superheater engines.

The operators who take the diagrams have only to note the serial number, and where possible, to mark the point on the road at which the card was taken on the continuous indicator ribbon. In the case of superheater engines, they record for each diagram, in addition to the serial number, the temperature of the saturated steam and of the superheated steam in the two compartments of the header, and the temperature of the hot gasses issuing from the large superheater flues.

These three indications are given by three special pyrometers which are conveniently placed, these being read at the same time as the cards are taken, or as soon as possible afterwards.

After the staff employed in making the tests have had a short period of practice, the system of signals and records given above works very well. Cases have been very rare in which one has had to reject the diagrams taken due to a lack of any of the data or through mistakes in transmitting the signals.

It may be well to say a few words on the determination of the speed at the instant at which indicators are taken, for this is a factor which has to be accurately determined in order to calculate the indicated horse-power and useful horse-power. The speed curve plotted as a function of the distance run is drawn on the dynamometer record by means of the Amsler speed recorder, and this answers very well as a rule to determine the instantaneous speed at the point at which the card is taken (this point being marked exactly by the operator who takes the card, on the line at the bottom of the dynamometer record by means of an electric contact). The instantaneous speed marked by the Amsler speed recorder may be compared with the average speed during the interval of time in which the indicator card was taken. This comparison is made with the object of eliminating data taken during intervals in which too great variations occur in the speed of the train.

A sufficiently accurate check may be made of the average speed at the moment at which indicator cards are taken by using the marks made for six seconds by the clock on the line at the bottom of the dynamometer record.

Although this does not give the instan-

taneous speed, this method gives with sufficient accuracy the value of the average speed over a definite period (30 to 60 seconds) with a sufficiently clear indication of the tendency of the train to accelerate or decelerate.

When it is necessary to analyse the secondary phases of the distribution which occurred at the end of a piston stroke (compression, lead, inside clearance) which, in the ordinary way are recorded at the end of the card, when the drum is moving slowly, one successfully uses the indicators in the following manner :

The drum of the indicator is driven from a piston whose crank is at an angle of 90° to that of the cylinder of which indicator cards are to be taken, this being as a rule the piston on the other side of the engine. In this way the movement of the indicator is in quadrature with that of the piston, and consequently events which occur at the end of the stroke are recorded in the middle of the card at the time when the drum is moving at its greatest speed, so that these events are very clearly shown. It is then easy to find the point corresponding to the dead centres, taking into account the correction necessary on account of the angularity of the connecting rod.

A similar study may be made of these events in the cycle by means of an indicator in which the paper is moved on a time basis, the dead centre being marked by means of an electric contact. A special indicator of this type also forms part of the equipment of a dynamometer car, and was constructed by the Italian Railway; it is a modification of the Crosby indicator.

From the foregoing, and from similar considerations, one may conclude, that the diagrams taken with the indicators throughout the whole of the series of tests, furnish information of a practical value, and that great accuracy can be obtained with the best apparatus of the kind employed for such purposes.

b) *Additional apparatus.* — To make a complete investigation of engine performances, the following additional apparatus is as a rule employed :

1° Recording pressure gauges for the boiler, steam chest, and for the receiver in the case of compound engines, sometimes also for the exhaust ports, especially in the case of superheater engines;

2° A recording vacuum gauge for the vacuum in the smokebox;

3° Recording pyrometers for the following :

*a*) The temperature of steam entering the cylinders (for saturated engines);

*b*) The temperature of steam in the receiver (for saturated compound engines);

*c*) The temperature of the steam in the exhaust (in the case of saturated engines this apparatus may be replaced by the pressure gauge mentioned in paragraph 1. In this way one obtains greater accuracy in determining the back pressure);

*d*) The average temperature in the smokebox;

*e*) The average temperature of combustion in the firebox;

*f*) The temperature of the products of combustion in certain groups of tubes when one wishes to investigate the relative efficiency of various parts of the boiler.

In order to make a comparison of the results obtained from trials on different locomotives, it is necessary that the figures should be completely comparable, and that the various apparatus should be always placed in a similar position on the locomotive. For example, the pipe of the recording vacuum gauge communicating with the smokebox always has its end fixed opposite the middle row of tubes and is turned

towards the smokebox door and extends to about 10 cm. (4 inches) from the blast pipe.

When it is necessary, a calorimeter is fitted which serves to measure the dryness of the steam, either in the steam pipe, or in the receiver, or to the base of the blast pipe, as may be required.

When, on the other hand, one wishes to investigate the influence of special steam dryers on the dryness of the steam, a calorimeter is applied on either side of the apparatus which it is required to test.

A summary of the data taken from the indicator cards, and from the additional apparatus, is always recorded on special forms, the important figures of which are shown on table B. We shall see later the methods of calculation employed in drawing up this table.

c) *Determination of fuel and water consumption.* — In nearly all the tests, fuel and water consumptions are taken.

To measure the water, one commences by calibrating the tanks of various tenders, by drawing up a table showing the differences in capacity for each centimetre of height in the tank.

One may then place on the tenders a glass indicating tube, protected by a brass cover which is provided with a window, and graduated so as to facilitate the reading of the exact quantity of water in the tender.

In each case a scale is marked off for every centimetre. It is good practice, however, where possible, to read the height of the water on both the right and left hand sides of the tender so as to take into account differences of level arising from difference in the rail level, or in the deflection of the springs, and to also take the height at the centre of the tender so as to eliminate error arising from gradients, or from variations in the loading of the tender.

Scales are also made for different boilers for the water gauge glasses so as to be able to record the difference of the level of water in the boiler at the same time as the quantity of water consumed is read from the tender. In order to take into account differences in the weight of water in the boiler which may occur for the same reading in the gauge glass, due to a possible difference in the pressure when taking the reading at the commencement and at the end of the test, as a rule preliminary tests are made so as to find experimentally for a given weight of water in the boiler, the variation of the level shown in the glass due to differences of pressure.

The figures for the coal consumed should represent the quantitiy of coal actually burned while running, excluding coal used for lighting up, but including the quantity required for making up the fire and raising the pressure from the average pressure when standing to the working pressure. Consequently, one includes the fuel put on the fire before starting, that is to say, from the time when the fire is made up with a pressure in the boiler of about 5 kgr. per square centimetre (71.11 lb. per square inch), provided that at the end of a trip a small correction is made for the differences which may exist between the amount of fire in the box when making up the fire on starting the journey and on arrival. The effect of these differences can obviously only be obtained approximately, and it rests entirely with the experimenter to make these allowances as uniformly as possible, taking into account the quantity and the condition of the coal remaining in the firebox. This can be done sufficiently accurately if one has practical experience of the road, and also of the engine under test.

The figures for coal consumption obtained by the results of the tests are always quoted as total consumptions, that is to say, without any deduction being made for what is left in the ashpan or in the smokebox. However, as a rule,

these quantities are also noted as an indication of the condition of combustion when running, and on the intensity of the draught, and as a check on the quality of the fuel compared with the data obtained from official tests of the coal supplied.

The coal used for the tests is, as a rule, that issued by the sheds to locomotives performing similar services to the engine under test. For each test, particulars are taken of the average chemical analyses of the coal used. In addition to these analyses the calorific value is taken (generally by means of a Mahler calorimeter) (1), the proportion per cent of volatile components, of ash and of fixed carbon, of moisture and sulphur. When one wishes to make very exact comparative trials, one uses throughout coal of the same quality and each lot of coal is analysed chemically, and the actual calorific value of the coal used is taken and compared with the average quality of coal used for the series of tests, that is to say that which is most like the average analysis obtained.

### II. — Composition of experimental trains and determination of the load hauled.

As a rule, the trains on which tests are carried out are goods trains or are run to the ordinary timings of through or express passenger trains. If necessary, the weight is made up with empty vehicles, wagons or coaches, as the case may be. It is only in the case of tests with special timings at high speeds, in order to obtain information on the running of express trains for long distances without stops, that special trains composed wholly of empty stock are used. This latter point should not be neglected in considering the work developed by the engines when making these tests, because for the same total load the total resistance of the train is greater for empty stock than when the coaches are occupied by passengers, especially on a level line at high speeds.

Determination of the load hauled is made as a rule, in the case of passenger trains, by taking the exact tare of the vehicles and adding a weight calculated in accordance with the number of passengers and the approximate weight of luggage and mails. In the case of freight trains, the tare weight and loads of the different vehicles is verified from the guards journal so as to obtain the greatest accuracy possible.

Details concerning the nature and number of the vehicles, the number of axles, and the loading for the different test trains, are always summarised in a table from which one can ascertain the differences between the tractive effort developed in various trials, these differences arising from the type of vehicles employed or from the loading of the same.

### III. — Tabulated results of the tests and their interpretation.

Tables are made of the information derived from the indicator cards taken from the different engines tested, and from the observations which are made at the same time as the diagrams are taken by means of other apparatus, and these are summarised in chapter V which follows, and to this is added a comparison of the useful tractive effort developed at the tender drawbar and the ratio between the indicated horse-power and the drawbar horse-power which is taken from information supplied by the dynamometer record.

Other tables prepared for the different engines tested and the different lines over which they are run which show particulars of the work performed and

(1) If one wishes to compare the results of analysis with other calorimeters, for example with a Thompson or Fery apparatus, it is necessary to take into account the methods of analysis to obtain the correct comparison of the qualities under consideration.

TABLE A. **Results of tests on work**

| Number and date of tests. | PLACES BETWEEN WHICH TESTS ARE CONDUCTED. | Actual length of test run, in kilometres. | "Virtual" length of test run, in "virtual" kilometres. | Load hauled, in tonnes. | Time taken, deducting stops, in seconds. | Average running speed, in kilometres per hour. | Average normal running speed, in kilometres per hour. | Total work done at the tender drawbar, in kilogrammetres. | Average tractive effort at the drawbar, in kilograms. | Average drawbar horse-power. | PARTICULARS REFERRING TO DISTANCE RUN REGULATOR OPEN. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $L_r$ | $L_v$ | P | T | V | $V_c$ | A | $F_u$ | $N_u$ | Distance run, in kilometres. | Corresponding time taken, in seconds. | Average corresponding speed, in kilometres per hour. | Average corresponding tractive effort, in kilograms. | Average drawbar horse-power. | Average ratio between indicated horse-power and drawbar horse-power. | Approximate average indicated horse-power. | Average effective horse-power at the rim of a wheel including air resistance. | Horse-power absorbed by internal resistance of the mechanism. |
| | | | | | | | | | | | L | T | V | $F_u$ | $N_u$ | $m$ | $N_i$ | $N_e$ | $N_i - N_e$ |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | | | | | | | | | | | | | | | | | | | |

the efficiency over the various trials run.

For the sake of brevity, one does not, as a rule, include in these reports the results obtained from certain tests of a simple preparatory nature and which present few points of final interest, since such information is included in the data furnished by the more complete tests which are subsequently carried out.

It must not be overlooked that the numerical information given in the tables, as well as that obtained from the indicator cards and dynamometer record, as regards the speed and power developed, which being the most important and most complete, are always shown in the tables in full. These do not represent work carried out under exceptional circumstances, but actual examples which may be obtained without special difficulty, provided the various classes of engines are properly handled.

We reproduce, as an example, table A, which gives the form in which the tabulated information obtained in a test run with a steam locomotive is drawn up.

In order to facilitate interpretation of the information given in table A, the following should be borne in mind (1):

1° The « virtual » distances $L_v$ for steam locomotives are taken from the *tables of « virtual » distances for the calculation of coal consumption,* which were published by the Administration of the State Railways in 1908, and which remain in force at the present time for experimental purposes. They are based upon the work done in hauling the train and the consumption of water and coal in steam locomotives. (See table A.)

The average train resistance per tonne on level and straight track has been taken as being 4 kgr. 5 (9.72 lb. per English ton). However, this has been increased to 5 kgr. (10.79 lb. per English ton) in order to include the portion of the coal burned when running, which is independent of the work done by the engine (radiation from the boiler, leakages, auxiliary apparatus, etc.). Under

(1) At the foot of the table, notes are always repeated giving the particular characteristics of the test to which the table applies where these are not common to all the tests.

nd water and coal consumed. TABLE A.

| power over whole journey. $N_i$ | Work done by engine in « virtual » tonne-kilometres hauled. $\Sigma$ | Work done by engine in « virtual » tonne-kilometres, including weight of engine and tender. $\Sigma'$ | WATER CONSUMPTION: Total water consumption, losses deducted, in litres. A | Total water consumption, after deducting water lost and steam for heating train, in litres. A' | per actual kilometre, in litres. $a_r$ | per « virtual »-kilometre, in litres. $a_v$ | per horse power drawbar hour, in litres. $a_u$ | per indicated horse-power hour, in litres. $a_i$ | per hour running, in litres. $a_t$ | per square metre of heating surface per hour, in litres. $a_s$ | per « virtual »-tonne-kilometre hauled, in litres. $a_\sigma$ | per « virtual »-tonne-kilometre, weight of engine and tender included, in litres $a_{\sigma'}$ | COAL CONSUMPTION: Total consumption, after deducting coal for lighting up and standing time, in kilograms. C | Total, after deducting for lighting up, standing time and heating train, in kilograms. C' | per actual kilometre, in kilograms. $c_r$ | per « virtual »-kilometre, in kilograms. $c_v$ | per drawbar horse-power hour, in kilograms. $c_u$ | per indicated horse-power hour, in kilograms. $c_i$ | per hour running, in kilograms. $c_t$ | per square metre of grate area per hour, in kilograms. $c_g$ | per « virtual »-tonne-kilometre hauled, in kilograms. $c_\sigma$ | per « virtual »-tonne-kilometre, weight of engine and tender included, in kilograms $c_{\sigma'}$ | Evaporation coefficient A / C | Weather conditions and general remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
| | | | | | | | | | | | | | | | | | | | | | | | | |

these conditions, the minimum « virtual » distance for down grades is equal to 1/10th of the actual distance. This minimum, however, has been increased to 1/5th to take into account the coal burned due to starting the train and to brake applications. As regards starting from rest, moreover, a minimum of one « virtual » kilometre has been adopted for each section between two successive stations.

Hence, neglecting curves, a « virtual » kilometre has been established on the basis of one kilometre added to the actual distance for 5 m. (16.40 feet) rise, and one kilometre less for 5 m. fall, the minimum being fixed on down gradients as one « virtual » kilometre for 5 actual kilometres (3.10 miles), and one « virtual » kilometre for each section between stations.

The figures given are worked out in accordance with the following formulæ :

$$L_v = L_r + \frac{h + \Sigma pl}{5} \quad \ldots\ldots (a)$$

$$L_v = \frac{1}{5} L_r \quad \ldots\ldots\ldots (b)$$

where

$L_r$ = actual distance in kilometres;
$h$ = rise or fall in metres, positive for a rise and negative for a fall;
$l$ = length in kilometres of each curve of the section under consideration;
$p$ = gradient in millimetres per metre equivalent to the curve (see coefficients given below);
$L_v$ = « virtual » length in kilometres.

The formula ($a$) is used for up gradients or level road and down gradients of less than 4 mm., and the formula ($b$) for down gradients equal to or greater than 4 mm. per metre.

In applying these, it is necessary as a general rule to consider separately the sections for which either formula is to be used, but an exception is made for short sections having regard in this case to the utilisation of kinetic energy.

The co-efficients adopted for expressing curvature as an equivalent gradient are based on actual tests with rolling stock on the Italian State Railways. These are increased by the actual incline

in the case of curves on an up grade and are decreased in the case of curves on a down grade. They are given in the following table :

**Resistance due for curvature.**

| Radius of curve in metres . . . . . | 1 000 | 900 | 800 | 700 | 600 | 500 | 450 | 400 | 350 | 300 | 250 | 200 | 180 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equivalent gradient or resistance in kilograms per tonne . . . . . | 0.5 | 0.6 | 0.8 | 1 0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.8 | 3.4 | 4.2 | 4.5 |

For intermediate radii, the correct value is obtained by interpolation.

Account is of course taken of the length of the curves in order to evaluate the average equivalent resistance due to these curves.

2° The total load hauled, P, is obtained in the manner given in the last paragraph but one of chapter II. The time taken T, in seconds, is obtained by deducting from the overall time the stops shown in the timetable, or by additional stops, but includes the time lost in starting stopping, or running at reduced speed.

3° The average running speed in kilometres per hour is obtained by dividing the distance run during the test by the time obtained as above :

$$V = \frac{3\,600\,L}{T}.$$

4° The average speed when running at full speed $V_c$, in kilometres per hour, is obtained on the other hand by deducting from the time T the time lost in starting up to the point when full speed is obtained, and that due to signal checks or speed reductions when making a stop. This can be easily obtained from the record made by the speed recorder in the dynamometer car.

The full normal speed $V_c$ is calculated as follows :

*a*) The distance $S_c$ over which full speed is maintained is obtained by taking the difference between the total distance S over which the test is made and the sum of the distances $S_1$, $S_2$, $S_3$, ... $S_n$ run during periods over which the speed is varying owing to acceleration or brake applications.

By examining the record of the Hasler speed recorder, one can directly obtain these distances, and these are measured by graphically integrating the areas by which they are represented.

We have consequently :

$$S_c = S - \Sigma_1^n S_n.$$

The time $T_c$ during which normal running speed $V_c$ is maintained is similarly given by the difference between the overall time T and the sum of the times $T_1$, $T_2$, $T_3$, $T_4$, ... $T_n$ taken to run the distances $S_1$, $S_2$, $S_3$, ... $S_n$. One can find the values of these times by counting on the paper record the little marks which form the speed curve. (See fig. 8 )

Hence :

$$T_c = T - \Sigma_1^n T_n.$$

The speed $V_c$ will therefore be given by the formula :

$$V_c = \frac{S_c}{T_c} = \frac{S - \Sigma_1^n S^n}{T - \Sigma_1^n T_n}$$

where the areas $Sn$ represent the distances over which acceleration or brake applications are taking place.

With the available information, one can directly calculate the time lost in starting $P_{2m+1}$ up till the normal run-

ning speed $V_c$ is attained and the time lost in the brake application $F_{2m}$ during which the full normal running speed $V_c$ decreases to zero.

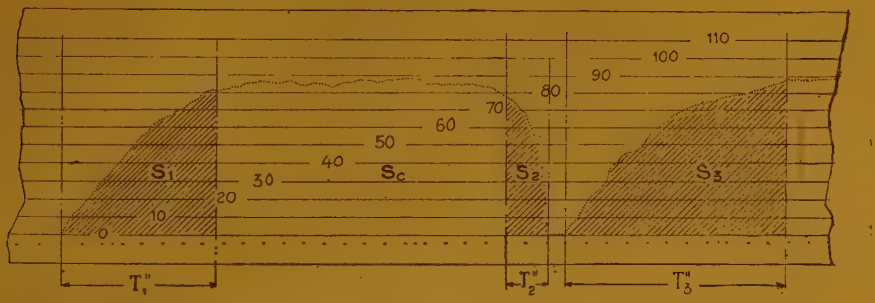


Fig. 8. — Hasler speed recorder record : determination of normal running speed of train.

It will be seen that the time lost is expressed by the difference between the time during which the train is starting or stopping, and the corresponding time which would have been necessary to run the same distance at the normal speed $V_c$.

Consequently, the formulæ to use are as follows :

$$P_{2m+1} = T_{2m+1} - \frac{S_{2m+1}}{V_c} \qquad (m = 0, 1, 2, \ldots)$$

$$F_{2m} = T_{2m} - \frac{S_{2m}}{V_c} \qquad (m = 1, 2, \ldots \ldots)$$

*b*) The same results may be obtained by using the Amsler speed recorder. The average normal running speed is still given by the foregoing method, the value $S_n$ being directly read on the horizontal scale of the paper record, while the value of $T_n$ is measured by the little marks made every six seconds on the same paper. The same applies for the time lost.

5° The total work done at the drawbar in kilogrammetres is deduced from the work integrator line of the dynamometer car. It may also be determined from the area included between the datum line and the tractive effort line drawn by the dynamometer.

6° The average drawbar pull $F_u$ is given by dividing the total work A by the distance run during the test :

$$F_u = \frac{A}{1\,000\ L_r}.$$

In column 10 of table A, the value of $F_u$ is given for the whole length of the test run. In column 15, on the other hand, the value is merely for the portion of the run during which the regulator is open.

7° In addition to the figures for the average power $N_u$ over the total length of the run, the table also gives, in italics, figures for the work done and power developed for the portion of the run during which the regulator is open. These figures in the first place give the exact indication of the average demand on the locomotive, and in the second place, furnish information for calculating the internal resistance of the engine itself, this being done as explained later.

The useful power developed at the tender drawbar, both for the total run and for the portion of the run during which the regulator is open, assuming that the dynamometer car is always turned in the normal direction, is given by the equation :

$$N_u = \frac{F_u V}{270}.$$

8° The average ratio $m$ between the indicated horse-power and the drawbar horse-power is determined for each individual test in which indicator cards are taken. Having obtained the ratio between the indicated horse-power and the drawbar horse-power corresponding to each indicator card, and after rejecting the cards which are not taken under the desired conditions, a curve is traced with the values of this ratio as ordinates and the speeds as abscissae giving values of $m$ corresponding to the average speed of the test run. Figure 9 gives an example of such a curve.

9° The mean effective power $N_e$ that is to say, the power developed at the rim of the wheel, excluding the internal resistance of the engine mechanism, is given by the following formula :

$$N_e = N_u \frac{P + M}{P} + \frac{\Omega K V}{270} \quad \ldots \quad (1)$$

where P represents the load hauled in tonnes, and M the total weight of engine and tender in working order (1); $\Omega$ the area of a locomotive in square metres, K the coefficient of air resistance which is assumed to have the value $K = 0.00567\ V^2$, this being the value given by Aspinall as a result of tests made in 1898-1900 on the Lancashire & Yorkshire Railway. The formula (1) may be taken as being sufficiently close for experimental purposes on normal types of locomotives. A value of V is taken which is equal to the relative speed of the train and of the air which is indicated by the anemometer on the dynamometer car.

It will be seen that the right hand portion of the equation (1) is the sum of two terms, the first of which is directly obtained from the value of a quantity which is measured experimentally in each particular case ($N_u$), while the second is furnished by a calculation based on the results of trials made by Aspinall and which have been found sufficiently good for speeds not exceeding 100 to 120 km. (62 to 74.5 miles) per hour.

In recent tests carried out by means of an aerodynamic tunnel, Messrs. C. Maurain, A. Toussaint and R. Pris have obtained, with models of 1/20th the full size of express rolling stock belonging to the French State Railways, interesting results as regards air resistance of rolling stock (1).

The empirical formula deduced by them for the value of the second term of the right hand portion of the equation (1) is :

$$N'_o = \frac{0.400\ K V^3}{75} \quad \ldots \quad (2)$$

It is to be noticed that the formula given by Aspinall gives results which are slightly higher to those given by the formula which we have just quoted, nevertheless, it is more applicable to the rolling stock employed on the Italian State Railways.

In ordinary calculations it is sufficient to take for the value of V the average speed maintained while running. This leads to no appreciable error as long as the average speed is less than 60 km. (37.3 miles) per hour, but if it is required to obtain exact figures for high speeds it is necessary to determine the average value of the term $KV^3$.

On the paper record of the Amsler speed recorder carried on the dynamometer car (fig. 10), one proceeds to divide up the base line (representing distances) into equal parts $\Delta S$ and to draw vertical lines through the points $A_1$, $A_2$, $A_3$, ... $A_n$; on these are marked off cor-

(1) The weight in working order of engine and tender is taken as having the average quantity of coal and water used during the tests (about two-thirds of the total capacity).

(1) See the *Génie Civil* for the 11 August 1923, pp. 138-139. Proceedings of the « Académie des Sciences », meeting held on the 23 July 1923.

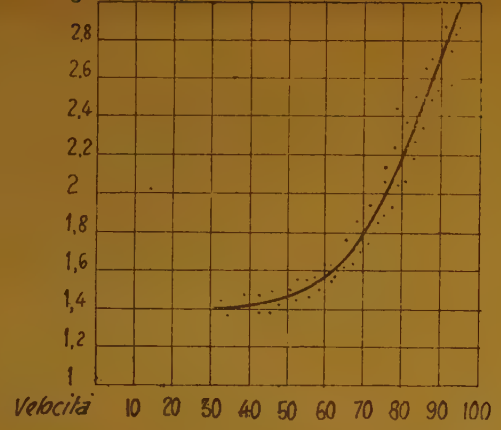


Fig. 9. — Example of curve showing $\frac{N_i}{N_{ii}}$.

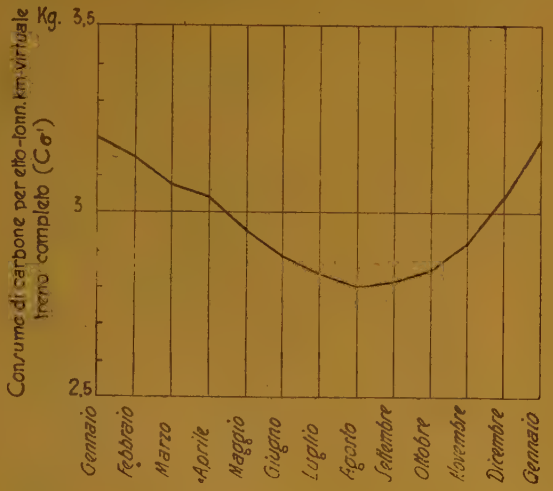


Fig. 12.

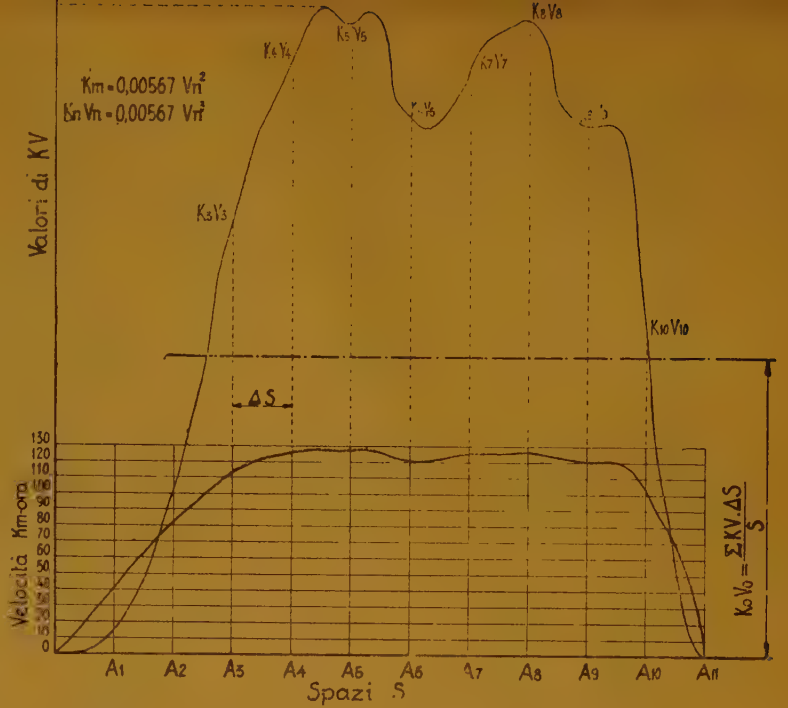


Fig 10. - - Graphical determination of the average value KV.

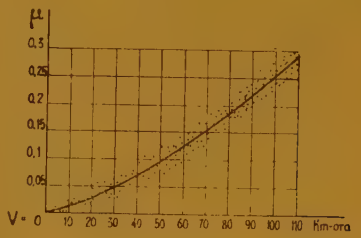


Fig. 11. — Curve showing mechanical efficiency of steam locomotive $\frac{N_i - N_e}{N_e}$.

*Explanation of Italian terms (figs. 9 to 12) :* Velocita = Speed. — Consumo di carbone per etto-tonn-km-virtuale, treno completo ($C\sigma'$) = Coal consumption per 100 « virtual » t.-km, including engine and tender. — Valori di KV = Values of KV. — Velocita Km-ora = Speed in km. per hour. — Spazi S = Distances S.

responding values of KV. We therefore have :

On point $A_1$ . . . . . $K_1 V_1 = 0.00567 V_1^3$

— — $A_2$ . . . . . $K_2 V_2 = 0.00567 V_2^3$

. . . . . .

— — $A_n$ . . . . . $K_n V_n = 0.00567 V_n^3$

The average value $K_o V_o$ is given by the relation

$$K_o V_o = \frac{\sum_1^n KV ds}{S} = \frac{0.00567 \sum_1^n V^3 ds}{S} ;$$

this being the value which is used in formula (1).

10° The ratio $\mu = \frac{N_i - N_e}{N_e}$ is useful as a criterion of the efficiency of a locomotive from the point of view of the internal resistance of mechanism.

For each locomotive tested, it is possible to obtain a series of values of $\mu$ corresponding with the different running speeds. In this way one can draw a mean curve of the results obtained experimentally, and thus produce a measure of the internal resistance of the mechanism for various running speeds (internal resistance of engines at various speeds, fig. 11).

11° The average indicated horse-power $N_i$ developed over selected portions of the total run are obtained by means of formulæ :

*a*) $N_i = mN_u$

*b*) $N_i = \left(N_u \frac{P + M}{P} + \frac{\Omega KV}{270}\right)(1 + \mu)$

The formula (*a*) is used for those tests during which indicator cards are taken, in which case the ratio *m* is obtained directly, and the formula (*b*) is used for tests in which indicator cards are not taken. In the latter case, mean values of $\mu$ for the various average speeds V for the total run are taken from a curve drawn by plotting the average of the value of the ratio $\frac{N_i - N_e}{N_e}$ obtained by the method given during tests in which cards have been taken.

12° The work $\Sigma$ performed by the engine at the tender drawbar expressed in « virtual » tonne-kilometres hauled is given by the equation :

$$\Sigma = P L_v.$$

The total work done, expressed in tonne-kilometres for the whole train, that is to say, including the weight of the engine and tender, is calculated by means of formula

$$\Sigma' = \Sigma + (30 + 0.7 M') L_v + (M' + M'') L_v \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where M′ and M″ are respectively the average weight of engine and tender in working order.

In this formula the first term in brackets represents the work necessary to overcome the internal resistance and the air resistance on the front of the engine, while the second term represents the work necessary to overcome the running resistance of the engine and tender considered as vehicles.

In this connection, however, we may mention that to calculate bonuses granted to footplate staff for fuel economy, the following formula has been adopted by the Italian State Railways :

$$\Sigma' = \Sigma + (30 + 1\ 7\ M' + M'') L_v \quad . \quad . \quad (4)$$

where the total resistance is taken relative to the « virtual » length of the trip, although the additional resistances of a locomotive are proportional to the actual length of run and not to the « virtual » length. This is done, however, to simplify office work and also to give a higher value to the work done on lines in mountainous districts, where, in view of the later cut-off which has to be used, the efficiency of the engine is somewhat reduced. It is only fair to

consider this latter point in allocating bonuses to the staff, although in the case of the tests which we are considering, it is on the other hand more logical to keep the two terms distinct; the one being proportional to the actual distance and the other proportional to the « virtual » distance, since it is necessary to obtain data from which the exact efficiency of the engine can be determined.

This point should be taken into consideration in comparing the figures given in table A with similar figures taken from the statistics of the locomotive department which deal with actual service conditions and which are obtained by means of formula (4) given above, instead of by formula (3).

13° The quantity of water consumed A, expressed in litres, is the total quantity less that lost at the injector overflow or used for coal watering, the deductions being made on the percentage basis established in the light of previous trials (1) or by means of observations made in each individual case. In the case of test trains fitted with steam heating, a similar deduction is made for the water and coal consumed for this purpose in accordance with information obtained experimentally, if necessary, by means of the method explained in chapter IV. The figures of the actual consumptions for hauling the train, as apart from these additional consumptions, are given in columns 26 and 36 respectively of table B. On the other hand, no deduction has been made for the steam used by the Westinghouse pump which was in action on all the engines tested, including banking engines used in mountainous districts, and freight engines which hauled non-fitted stock.

By means of the figures obtained from the net coal and water consumption, figures are obtained for the consumption per unit of work which appear in the other columns of the tables.

For example, the consumptions of water $a_r$ and of coal $c_r$ per actual kilometre run and $a_v$ and $c_v$ respectively per « virtual » kilometre are given by the equations :

$$a_r = \frac{A'}{L_r}; \quad a_v = \frac{A'}{L_v}; \quad c_r = \frac{C'}{L_r}; \quad c_v = \frac{C'}{L_v}.$$

The water consumption $a_u$ and coal consumption $c_u$ per drawbar horse-power-hour are given by the equations :

$$a_u = \frac{270\,000\,A'}{\Lambda}; \quad c_u = \frac{270\,000\,C'}{\Lambda}$$

and the consumptions $a_i$ and $c_i$ per indicated horse-power-hour are given by (1) :

$$a_i = \frac{270\,000\,A'}{m\Lambda} = \frac{3\,600\,A'}{T''\,N_i};$$

$$c_i = \frac{270\,000\,C'}{m\Lambda} = \frac{3\,600\,C'}{T''\,N_i};$$

the coal and water consumed per hour running are given by :

$$a_t = \frac{3\,600\,A'}{T''}; \quad c_t = \frac{3\,600\,C'}{T''},$$

while the water evaporated per hour per square foot of heating surface and the coal burned per hour per square metre of grate area are given by :

$$a_s = \frac{3\,600\,A'}{T''\,S}; \quad c_s = \frac{3\,600\,C'}{T''\,G}$$

where S is the total heating surface of the locomotive and G the grate area in square metres.

(1) A number of actual tests made during the trials show that the water lost at the injector overflow may be taken normally as being about 2 % of the total water consumed.

(1) It should be noted that when $m$ is known, it is preferable to employ the formula $a_i = \frac{270\,000\,A'}{m\Lambda}$ for determining $a_i$, for in this case only two experimental determinations are required, while for the formula $a_i = \frac{3\,600\,A'}{T''\,N_i}$ three quantities have to be determined. The same remarks hold good for the value of $c_i$.

TABLE B. **Summary of information tak**

| Number of test. (1) | Load hauled, in tonnes, P. (2) | Number of diagram. (3) | Corresponding speed V, in kilometres per hour. (4) | Number of revolutions per minute. (5) | Useful effort at the drawbar, in kilograms, $F_u$. (6) | Useful horse-power at the drawbar $N_u$. (7) | Boiler pressure, in kilograms per square centimetre. (8) | Pressure in steam chest, in kilograms per square centimetre. (9) | Pressure in receiver, in kilograms per square centimetre, $p_r$. (10) | Temperature of superheated steam entering cylinders, in degrees C. (11) | Temperature of steam in the receiver, in degrees C. (12) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |

The coal consumption per « virtual » tonne kilometre (excluding engine and tender), and per « virtual » tonne kilometre (including engine and tender) are given by :

$$a_\sigma = \frac{A'}{\Sigma}; \quad c_\sigma = \frac{C'}{\Sigma}; \quad a_{\sigma'} = \frac{A'}{\Sigma'}; \quad c_{\sigma'} = \frac{C'}{\Sigma'}.$$

The ratio

$$\frac{A}{C} = \frac{A'}{C'} = \frac{a_r}{c_r} = \frac{a_v}{c_v} = \frac{a_u}{c_u} = \frac{a_i}{c_i} = \frac{a_t}{c_t} = \frac{a_s}{c_s}$$

may for the same series of tests be taken as being proportional to the evaporation coefficient. In practice, the evaporation coefficient obtained in this way should be corrected so as to include the influence due to the mean temperature of the feed water, the average boiler pressure, and in case of saturated locomotives, to the average dryness of the steam used. In the case of superheater engines, account must also be taken of the average temperature of superheat and the corresponding specific heat. When a discrepancy appears in the evaporation coefficients, it is obvious that they are not comparable except when they are obtained in the course of similar experiments and are obtained by identical methods. In each case the coefficient as given by the result of the tests represents the ratio between the actual water consumed (losses deducted) and the coal burned (coal used for lighting up deducted), and as such they are of immediate practical value.

In column 46 of the table, which is provided for remarks, are indicated the number of minutes gained or lost during the running of each test train and the number of stops.

The time gained or lost is calculated by comparing the time actually occupied in running, with the booked timings, the latter being increased to allow for loss of time due to service slacks and for time lost in making signal stops. This information is taken from an analysis of the speed record.

The time lost is shown as time gained with a negative sign.

14° It sometimes occurs that a series of dynamometer trials for steam locomotives are extended for a sufficiently long period to obtain experimental comparison of results obtained during different seasons of the year.

In this case, in order to draw a proper comparison, it is useful to determine the

a indicator diagrams.

TABLE B.

| Cut-off per cent of stroke. (14) | | Mean effective pressure, in kilograms per square centimetre. (15) | | Indicated horse-power. (16) | | Ratio of power in low pressure cylinders to total power. (17) | Total indicated horse-power $N_i$. (18) | Ratio $\frac{N_i}{N_u}$. (19) | Vacuum in the smokebox, in millimetres. (20) | Temperature of exhaust steam, in degrees C. (21) | Total indicated tractive effort $F_i$, in kilograms. (22) | *Remarks.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P. | L. P. | H. P. | L. P. | H. P. | L. P. | | | | | | | |
| ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | |

total results of the difference in temperature which one may obtain in the best season as compared with the worst season (loss due to radiation of the boiler, difference of temperature of the feed water and of the air entering the firebox, etc.).

For this purpose we use the following indirect method : The coal and water consumption per unit of work expressed in « virtual » tonne-kilometres for the whole train ($a_\sigma'$, $c_\sigma'$) is obtained from the locomotive department accounts, deducting the coal used for lighting up and steam raising, these figures being applicable to a group of engines of the same type or of a similar type and used on similar service as for the test trains. We then draw a curve of consumptions which is taken as a mean of the consumption per unit of work for each locomotive, and for each month, the figures extending, for example, over two or three years (either calendar of financial).

This curve will represent the variation in the unit consumption for the various months of the year for the group of locomotives under consideration, and the diagram will be of greater use in accordance with whether the group of engines under test are working under similar conditions both as regards the trains which they work and the care which the footplate staff take in saving coal.

For the latter reason, these curves can only be drawn when an individual bonus is given for each engine of the group under consideration.

The curve thus drawn will be similar to that shown in figure 12. From the numerical values of this curve, one can obtain for any season of the year the percentage by which the consumption figures obtained during dynamometer trials must be corrected, as mentioned above, to make them comparable with results obtained at different periods of the same year.

### IV. — Determination of the steam and coal consumed in heating the test trains.

If the tests are carried out with ordinary trains, steam has to be supplied to the heating pipe so as to maintain a normal temperature in the different compartments, and it is necessary to obtain the requisite data to separate from the total consumption the part which is required by the heating apparatus.

At the beginning of a trial, the steam heating valve on the engine is fixed in an open position so that there is sufficient steam to ensure that the train shall always be heated without having to again adjust the valve.

In every case the initial pressure is less than one half the boiler pressure, and consequently one can consider the flow of saturated steam passing through the valve as a flow through a small orifice.

It is well known that the critical pressure in the *vena contracta* of the jet and the corresponding velocity $W_c$ is independent of the pressure existing on the discharge side of the orifice, but for dry saturated steam depends solely for an orifice of any given area on the pressure $p$ at the inlet side (locomotive boilers produce fairly dry steam and the throttling through the valve on the boiler through which steam is taken serves to somewhat dry the steam), the value of $p_c$ and $W_c$ being given by the following equations :

$$p_c = 0.574\, p_1$$
$$W_c = 3.227 \sqrt{p_1 v_1}.$$

The boiler pressure can be maintained approximately constant throughout the duration of the test, as in practice it varies through a very small range.

Moreover, it will be seen that during the tests the variation of the pressure is recorded by a recording pressure gauge and therefore it is always possible to obtain the mean boiler pressure. Consequently the experimenter can make certain that the pressure in the pipe on the train pipe side of the warming valve is always less than the critical value $p_c$; thus, if the area of the orifice and the pressure $p_1$, remains constant, the quantity of steam passed will only depend upon the duration of the test.

In practice, for each series of tests, one determines the proper working position of the steam valve, and the corresponding steam consumption can be made from the preliminary standing test. This consumption is independent, as shown above, of the pressure in the train pipe. The experimental results thus obtained are not theoretical quantities which may be affected by various errors due to the apparatus.

After having determined the steam consumed in steam heating, one obtains the equivalent coal consumption by means of the average evaporation coefficient for the boiler obtained during the test $\left(\frac{A}{C}\right)$

### V. — Summary of information taken from the indicator cards.

We give in table B a summary of the results obtained with these instruments.

The load P is the same as in table A.

The speed V is the average speed over the short interval of time during which the indicator card is being taken, as explained in chapter I.

The force exerted at the drawbar $F_u$ is obtained by the equation given in chapter III, paragraph 6.

The drawbar horse-power developed $N_u$ is obtained by the formula given in chapter III, paragraph 7.

The regulator opening is given as a fraction of the total opening. This is checked on the engine when not in steam.

The mean effective pressure for each side of the engine is the average of the areas of the diagrams for the two ends of the cylinder.

The indicated horse-power is calculated by the formula :

$$N_i = p'_m V\alpha + p''_m V\beta$$

where $p'_m$ and $p''_m$ are the mean effec-

tive pressures of the diagrams referred to above, V is the speed in kilometres per hour corresponding to each diagram (see column 4, table B), while :

$$\left.\begin{aligned} \alpha &= \frac{1\,000}{3\,600 \times 75} \times 10\,000\,(d^2 - \delta^2)\,\frac{l}{D} \\ \beta &= 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \end{aligned}\right\} \text{for 2 cylinder simple engines.}$$

$$\left.\begin{aligned} \alpha &= \frac{1\,000}{2 \times 3\,600 \times 75} \times 10\,000\,(d_1^2 - \delta_1^2)\,\frac{l}{D} \\ \beta &= \frac{1\,000}{2 \times 3\,600 \times 75} \times 10\,000\,(d_2^2 - \delta_2^2)\,\frac{l}{D} \end{aligned}\right\} \text{for 2 cylinder compound engines.}$$

$$\left.\begin{aligned} \alpha &= \frac{1\,000}{3\,600 \times 75} \times 10\,000\,(d_1^2 - \delta_1^2)\,\frac{l}{D} \\ \beta &= \frac{1\,000}{3\,600 \times 75} \times 10\,000\,(d_2^2 - \delta_2^2)\,\frac{l}{D} \end{aligned}\right\} \text{for 4 cylinder compound engines.}$$

In these expressions the values of $d$, $d_1$, $d_2$, $l$ and D, in metres, represent respectively the diameters of the cylinders, the stroke and the diameter of the driving wheels, $\delta^2$, $\delta_1^2$ and $\delta_2^2$ also in metres, represent the values of half the sum of the squares of the diameters of the piston rods and tail rods.

In column 22 the indicated tractive effort $F_i$ is obtained from the equation :

$$F_i = mF_a = \frac{270\,N_i}{V}.$$

It is scarcely necessary to add that each series of tests consists of a number of individual tests which are not affected by the serious errors (which are always found in any one particular test) and the numerical results for each series of tests represent the averages of the results which are found to agree substantially between themselves. The reliability of average results which are thus compiled and checked is incontestable, and the remarkable agreement is always found between the results of these tests and evidence of practical experience under service conditions with engines of the same type.

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# DERAILMENTS OF LOCOMOTIVES ON CURVES.

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Figs. 1 to 9, pp. 2558 to 2566.

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Those who are called upon to investigate the causes of locomotive derailments are frequently puzzled to know what to say in their reports. An investigation of the locomotive does not disclose any mechanical defect and the track seems to be in perfect condition. The operating conditions at the time of the derailment were satisfactory, and still the locomotive left the track. In many cases there does not seem to be any one factor or combination of factors at which to point the finger of blame.

One of the most common derailments on a curve is that in which the outside leading driver climbs the rail while the locomotive is moving at slow speed. Such derailments usually occur with some one class of locomotives, under certain definite conditions as to degree of curvature and track elevation, and operating conditions peculiar to the locality. Occasionally the second driver will also figure in a derailment. Such derailments, while causing very little property damage, are costly and exasperating. They tie up the line, cause delays and annoyance and frequently require the use of the wrecking outfit because of the heavy locomotives which are usually involved. This discussion, which is based on a study and investigation of a number of such derailments, is made in an attempt to show what might be the causes of such derailments, and where to look for the trouble when these derailments take place.

It is practically impossible to arrive at exact values for the forces and stresses that occur in the locomotive and track, by a method of analysis. This is owing to the varying conditions found and the assumptions which must necessarily be made. Yet this is the only method that the majority of engineers have for arriving at conclusions in regard to such derailments. There are instruments for determining the thrusts exerted by locomotive drivers on the rail, but these instruments are costly. Their use requires a great deal of preparation and time and they require considerable care in handling, as well as in the interpretation of results. Such apparatus is not available to the average mechanical officer for his investigations. Therefore, it is necessary to study the case analytically with the hope of shedding some light on the problem to the end that faulty conditions will be corrected and future derailments prevented.

The locomotives involved in the de-

railments which led up to this discussion were of the heavy Mikado and Santa Fe types. The speeds were slow, not over 10 miles per hour, and it was usually the outside leading driver which was derailed. Sometimes it was both the leading and second drivers that climbed the rail. There were instances where the locomotive had traveled considerable distances before the engineman was aware that a derailment had taken place. These derailments took place on curvatures of from about 4 to 12°.

In order to simplify this discussion, the writers have chosen to include only the Santa Fe type of locomotive. The principles involved, however, apply equally well to any other type of locomotive. Furthermore, as these derailments took place at low speeds, the conditions were considered to be static rather than dynamic and centrifugal force would therefore have little effect and was not taken into account in this study.

This discussion is intended to be qualitative, rather than quantitative. It is desired to point out the principles rather than to give definite figures for any particular locomotive and for this reason the figures used in this article and the selection of the Santa Fe type are solely for the purpose of illustrating and giving a definite form to these principles.

### How a locomotive traverses a curve.

Apparently a locomotive rolls around a curve with little effort, but when curve friction is taken into account, train resistance formulas show that the work to be done in curving is a factor to be reckoned with. Suppose a locomotive going east passes around a curve after which it is traveling north. During the time the locomotive has gone around the curve it has rotated about some point in its wheel base through an angle of 90°. That is, while it was rolling ahead, it was also slipping sidewise; the treads of the wheels slipping laterally on the tops of the rails. It is evident that there must also have been a longitudinal slipping of some of the wheels, because the distance around the curve on the outer rail is longer than the distance on the inner rail. These lateral and longitudinal slippages, or their components, must be overcome to get the locomotive around the curve and the work must be done by the flanges. At high speeds, centrifugal force must also be overcome, but its effect is very small at slow speeds. In order to fix these ideas clearly in mind, consider a locomotive without flanges to be traversing a curve on a plane surface without rails, as shown in figure 1. The traction of the locomotive if not guided would cause it to move in the direction of the arrow X. But it is desired to make it move in the curved path AB. In order to do this it is necessary that pulling forces be applied at the front and back, as at Y and Z, or pushing forces, as at Y' and Z' or combinations of these forces, at the same time that the tractive force is acting. By regulating the amounts of the forces Y, Y', Z and Z' in conjunction with the tractive force, the locomotive will follow the curved line AB without the use of rails and flanges. Instead of the large forces Y, Y', Z and Z', we could employ a larger number of smaller forces as *a*, *b*, *c*, *d*, *e* and *f*. It will be observed that the forces Y and Z, or the larger number of smaller forces, cause the whole locomotive to rotate about some point in its wheel base and that the location of the point of rotation can be varied by altering the forces.

Now consider that this locomotive, still without flanges, is placed on the track. If the rotating forces are just right, the locomotive will go around the curve safely. The action of the pairs of wheels will be the same as large cylinders which tend to roll at right angles to their axes, as indicated by the arrows in figure 2. Thus first, second and third pairs of drivers tend to roll off on a tangent to the curve and leave the rail on

Fig. 1. — A locomotive without flanges on a plane surface without rails.

Fig. 2. — A locomotive without flanges on a track.

Fig. 3. — Position of a locomotive tends to assume when the guiding forces are removed

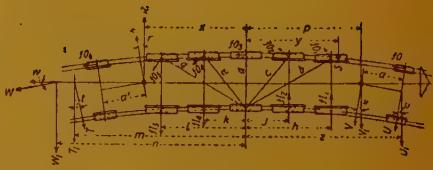

Fig. 5. — The forces and reactions of a locomotive when curving.

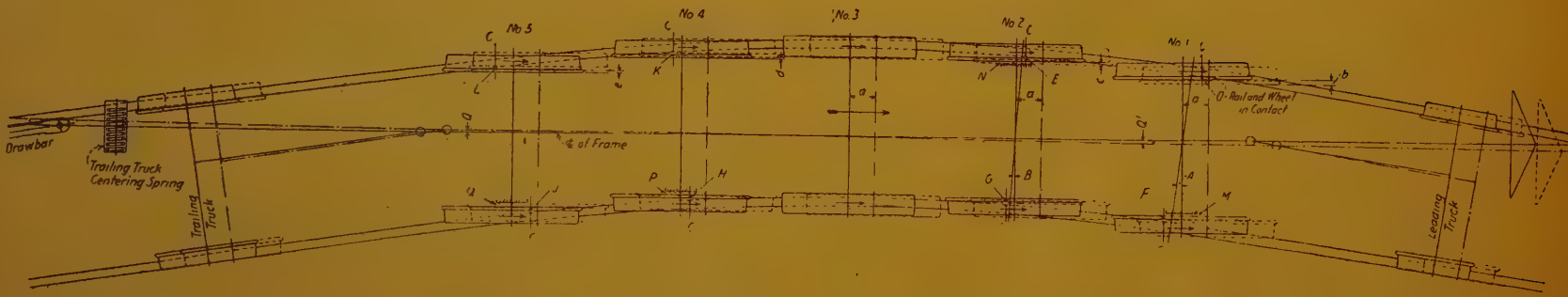


Fig. 4. — A locomotive on a curve, showing a first and succeeding position.

the outside of the track and the fourth and fifth pairs of drivers tend to roll over the rail on the inside of the track. So if the guiding forces are removed, or are too small for the work to be done, the locomotive will assume the position shown in figure 3.

**Position of a locomotive on a curve.**

With these ideas in mind, consider figure 4 which shows the position of the drivers of a Santa Fe locomotive on a curve. The solid lines are the position of the locomotive at any instant and the dotted lines at any succeeding instant. The curvature of the track shown in the drawing is exaggerated for clearness.

The locomotive is moving in the direction of the large arrow. The axles are held parallel to each other by the frame and with the possible exception of the main axle, make angles with the radii of the curve, as shown at A and B. The angularities between the axles and the radii cause similar angularities between the flanges and rails, which are commonly termed the striking angles. Thus the wheels roll, with respect to the rails, as shown by the small arrows on each wheel. This shows how the outside number one and two drivers tend to climb over the outer rail and the inside number four and five drivers tend to climb over the inner rail. Furthermore, the striking angles cause the points of contact between the wheels and rail to move ahead of the centers of the outside number one and two and inside number four and five drivers, and back of the centers of the opposite wheels. The locations of the points of contact are on the lines C. The distances from the centers of the wheels to the lines C depend upon the curvature, the length of wheel base and the position of the wheels in the wheel base.

Whether or not there is actually contact between the wheel and rail on the lines C depends upon the curvature of the track and the lateral play between the backs of the drivers and the journal boxes. Any curvature will cause the number one wheel to roll against the outer rail and cause contact at D and any curvature would cause the number two wheel to roll against the rail at E, if the frame of the locomotive did not exert a force to hold it away. It has been found that a locomotive just out of the shop, with the lateral taken up, will have contact between the flange of the second driver and the rail at E up to about 4° of track curvature, after which there is clearance at E. This explains why derailments do not take place so commonly under 4°, for below that curvature, there are two driving wheel flanges doing the work of guiding instead of one. But when the departure of curvature becomes too great for the driving box lateral, as it does from about 4° upward, the flange is pulled away from the rail at E., the assistance that the number two flange has been giving is withdrawn and the number one flange must take on the extra load. Naturally, there is clearance at the opposite points shown at F and G, for these drivers tend to roll away from the inside rail. In spite of the fact that the inside number four and five drivers tend to roll over the inside rail toward the inside, an observation of locomotives on curves shows there is clearance at H and J, as well as at K and L. We naturally expect a clearance at K and L due to the direction in which these wheels roll with respect to the outer rail, but the clearance at H and J can only be explained by the fact that the center of rotation must be somewhere ahead of the number four drivers. It may be noted, as a deduction, that the maximum curvature which the locomotive will take without complete binding is that which will cause contact at the points D, L, G and H.

Because these derailments give trouble when the number two flange does not bear against the outer rail, this study

has been limited to that condition. The outside number one hub bears against the frame, putting all the lateral in the number one pair of drivers at M, while the frame rotates in the direction of the curve. This rotation of the frame causes it to bear against the inside number two and outside number four and five hubs, which places the lateral in those drivers at N, P and Q, respectively.

### Succeeding positions of a locomotive on a curve.

Consider the locomotive in figure 4 to have moved the distance *a* to the position shown by the dotted lines. After the locomotive has fully entered the curve, other conditions being equal, the contacts and clearances at the hubs, will remain constant until the locomotive starts to leave the curve. It will be observed that while the locomotive has moved ahead the distance *a*, the number one drivers have moved to the right the distance *b;* the number two drivers have moved to the right the distance *c;* the number four drivers have moved to the left the distance *d*, and the number five drivers have moved to the left the distance *e*. Thus it will be observed that a locomotive does not simply roll around a curve, but that it both rolls and slides around the curve with a sidewise slipping of the wheels, and that for each longitudinal advance there is a corresponding lateral slipping. This a nothing more nor less than a lateral rotation of the locomotive, the rolling of the wheels and longitudinal advance having little to do with it, except to make the necessary rotation. This rotation is shown by the positions of the center lines of the locomotive in figure 4, the center of the locomotive having been rotated through the angle Q'.

### The center of rotation.

The center of rotation varies for different types of locomotives, curvatures of track, speeds and locomotive and track conditions. It will vary even for any given locomotive and curvature with the slightest amount of variation of speed, track elevation, surface and alinement, as the throttle is opened or closed, or as the brakes are applied or released. However, for the conditions selected, it may be definitely located on the inner rail, approximately under the main driving wheel. Owing to the elevation of the outer rail and low speed with the absence of centrifugal force, the most slipping will occur under the outer drivers and not the inner, as the outer drivers carry less load than the inner for these conditions. Therefore rotation takes place about some point on the inner wheel base. Furthermore, if the point of rotation is at or back of the contact point of the number four driver, the clearance at H would become zero, as this wheel rolls in the direction of the arrow, which it does not do in practice. Therefore the point of rotation is somewhere ahead of the number four driver, and it will have to be an appreciable distance ahead of this driver to maintain the clearance at H. Finally, if the point of rotation is appreciably ahead of the main driver, the distance from the center of rotation to the contact point of the number one driver at D would be less than the distance from the center of rotation to the contact point of the number five driver at L, so that a given lateral movement at D would produce a greater lateral movement at L taking up the clearance at L, which again is not borne out in practice. Therefore the center of rotation must be near the inside main driver. A small variation in the location of this point will not affect the principles involved nor materially affect the numerical calculations. Thus for the sake of simplifying both the analysis and computations, this point will be considered as being at the center of the tread of the inside main driver.

**Forces to be overcome in rotating.**

We have seen that the rotating forces must overcome the lateral slipping of all the driving wheels, or the diagonal components thereof, except that of the inside main driver, about which the rotation of the locomotive takes place. There is also a longitudinal slipping of the outer wheels, due to the fact that the distance around the curve on the outer rails is longer than the inner and that the outer wheels carry a lighter load. This longitudinal slipping, or its diagonal component, must be overcome as well. The trailing truck, or the leading truck, when the locomotive is backing, also exerts a force opposite to the direction of curving, and this too, must be overcome. Finally, the pull of the drawbar has a component which adds its share to the already heavy burden of the rotating forces. In all of this it must be kept in mind that centrifugal force is not considered to be a factor at these low speeds. Each of the forces to be overcome may be analyzed and evaluated.

These forces can be more clearly understood by referring to figure 5. If $O_1$ is the weight on the outside number one driver, $O_2$ the weight on the outside number two driver, $I_1$ the weight on the inside number one driver, etc., and $f$ the coefficient of friction between the wheel and rail, then the forces $fO_1$, $fO_2$, $fI_1$, etc., are the forces required to cause sliding of the wheels, longitudinally in the case of the outside main driver, laterally in the cases of the inside number one, two, four and five drivers and both longitudinally and laterally, or diagonally, in the cases of the outside number one, two, four and five drivers.

**Driving wheel friction.**

In arriving at the loads on the drivers, we must bear in mind that the elevation of the outer rail causes the center of gravity of the locomotive to the thrown toward the inside of the curve, thus taking weight off the outside wheels and putting additional weight on the inside wheels. This can be understood from

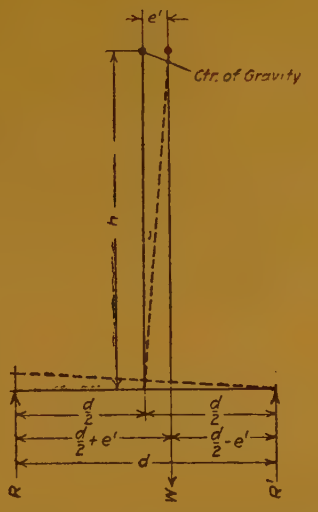


Fig. 6. — Diagram showing the effect of the elevation of the outer rail.

figure 6, in which the solid lines show the locomotive when horizontal and the dotted lines show the locomotive when on a curve with the elevation $e$. Suppose $h$ to be the height of the center of gravity above the top of the rail and $d$ the distance from center to center of the tops of the rails. Then $e'$, the distance the center of gravity will move toward the inside of the curve, is $\frac{eh}{d}$. Also the reactions R and R′ due to the load W being off center will be

$$R = \frac{w\left(\frac{d}{2} - e'\right)}{d} \quad \text{and} \quad R' = \frac{w\left(\frac{d}{2} + e'\right)}{d}.$$

These wheel loads are to be used for O and I respectively.

In selecting a value for the coefficient of friction $f$, a study of the data and tables given by various authorities, and

also of the results of investigations made at The Pennsylvania State College shows that it varies from 0.10 to 0.41, and that a fair value for steel tires on steel rails would be about 0.20. In selecting this figure, it was borne in mind that the coefficient of friction would be less for a revolving wheel than for a stationary wheel, as shown by the fact that a plug gage can be slipped more easily into a ring gage if it is revolved at the same time it is pushed in. It may also be noted here that the coefficient of friction of rest is greater than that of motion, and that this coefficient decreases in value as the speed increases. We would, therefore, naturally expect derailments to occur on curves of moderate curvature, say up to about 12°. The speed of lateral slipping, for any given locomotive speed, increases with the curvature, and therefore the coefficient of friction of lateral slipping for the higher curvatures, being less, does not cause such a high side thrust of the outer wheel.

### Trailing truck action.

Trailing trucks are of various types, but suppose we have one of the sliding type with a centering spring. This spring is compressed on a curve, and

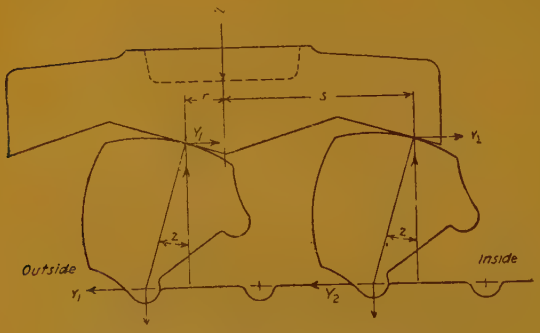


Fig. 7. — Reactions in the leading truck.

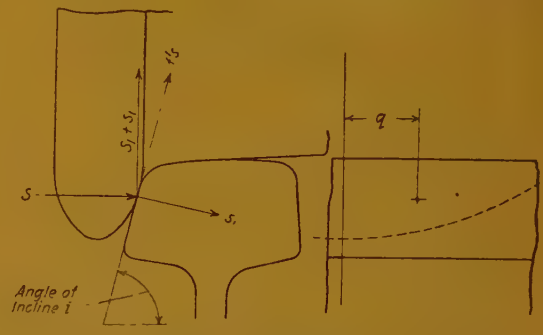


Fig. 8. — Relation of the horizontal to the vertical forces at the wheel.

exerts a pressure on the locomotive frame toward the inside of the curve. From the known dimensions of the spring we have the diameter of the steel *d*, the mean radius of the coil *r* and the number of coils *n*. Also from the conditions of the curvature, we know the deflection F. Then from the formula

$$T = \frac{FGd^4}{64nr^3}$$

we are able to calculate the force T, which is exerted by the spring, taken the modulus of torsional elasticity, G, at 12 500 000. This force is not at right angles to the frame but is transmitted to the frame through the usual ball and socket connection. Therefore we must consider the component normal to the frame, which is $T_1 = T \cos t$. Trailing trucks of the rocking or other types would be considered in a similar manner, except that in these types the load is applied on the center of the truck, whereas when centering springs are employed, the load is applied at a considerable distance back of the truck center.

### Effect of the drawbar pull.

When the locomotive is pulling a train or even the tender, there is a side thrust to be considered, the intensity of which will depend upon the curvature and the

actual drawbar pull. We shall include this factor in the study and set for it a figure based on a nominal drawbar pull of 30 000 lb. In making investigations this factor will have to be studied carefully in order to be evaluated properly. Referring to figure 5, the side thrust of the drawbar pull is $W_1 = W \tan w$.

**Moments of forces to be overcome.**

Thus we must overcome the forces $fO_1$, etc., $fI_1$, etc., $T_1$ and $W_1$, the intensities of which have just been analyzed. Since we have considered rotation to take place about the inside main driver, the moment arms of these forces are *b*, *c*, *d*, etc., as given in figure 5. Summing up these factors, in order to cause the locomotive to rotate about the inside driver, we must exert sufficient turning moment to overcome these resisting moments which are

$$bfO_1 + cfO_2 + dfO_3 + efO_4 + gfO_5 + hfI_1 + \\ + jfI_2 + kfI_4 + lfI_3 + mT_4 + nW_4.$$

**Overcoming the reactions.**

Opposed to the above forces are reactions which must cause sufficient turning moments to balance those of the resisting forces if a derailment is not to occur. First of all, we have the guiding reaction of the leading truck wheel flange and then the reaction of the leading driving wheel flange. Owing to the conditions already assumed, there are no other flange reactions. Assisting the two flange reactions are the lateral components of the side thrusts of the leading truck radius bar pin and of the trailing truck radius bar pin. Truly the reactions are few compared to the resisting forces and consequently they must be high in numerical value to meet the work they are called upon to do. Referring again to figure 5, the leading truck reaction is U with its lateral component $U_1$; the leading driving wheel reaction is S; that of the leading truck radius bar center pin is V, with its lateral component $V_1$, and that of the trailing truck radius bar pin is R, with its lateral component $R_1$.

**An analysis of the reactions.**

As in the case of the trailing truck, there are also various kinds of leading trucks; and for purpose of analysis one of the constant resistance, rocker type has been selected. Referring to figure 7, let the load on the truck be Z. This load will then have the vertical reactions at the rockers of

$$Z_1 = \frac{Zs}{r+s} \quad \text{and} \quad Z_2 = \frac{Zr}{r+s},$$

respectively. The horizontal components of the reactions are $Y_1 = Z_1 \tan z$ and $Y_2 = Z_2 \tan z$ respectively, which, added together, equal U in figure 5. U has its lateral component which is $U_1 = U \cos u$. The reaction of the leading truck radius bar pin causes the wheels to follow the curve radially. In order to do this the reaction of the pin must be sufficient to cause the slipping of one of the wheels, at least when the coning is not precisely right, as is generally the case, all because the outer and inner rails of the curve are not the same length. Because the outer wheel carries the lesser weight, it is the one to slip and the force required to slip it is *f*O. If *d* is the distance from center to center of the rails, as in figure 6, and *a* the distance from the pivot pin to the center of the truck as in figure 5, then by taking moments about the inside wheel, the reaction is

$$V = \frac{fOd}{a}$$

and its lateral component is $V_1 = V \cos v$.

The reaction of the trailing truck radius bar pin is due to the same cause as the reaction of the leading truck radius bar pin and may be found in a similar manner. Thus let *d* again be the distance from the center of rail head and *a'* the distance from the pivot pin to the center

of the truck. Then by taking moments as in the case of the leading truck, the value of the side thrust is

$$R = \frac{dfO_6}{a'}$$

and its lateral components is $R_1 = R \cos r$. The reaction of the leading driver will be considered as the unknown and when once determined, it will enable us to tell whether or not that wheel will stay on the rail. Thus by using the moment arms given in figure 5, in a manner similar to that used for the resistances, the combined moments of the rotating reactions are $zU_1 + yS + xR_1 + pV_1$, in which S is unknown.

**The vertical reaction.**

This horizontal thrust S has a vertical reaction $S_1$ which is opposed by the weight on the driving wheel. If the weight is not sufficient to overcome the reaction $S_1$, a derailment will result. The relation of the wheel and rail is shown in figure 8, in which the rail is curve-worn, as that is usually the condition in which the rail is found when a derailment takes place. The relation is similar to that of an inclined plane, the thrust S producing the normal reaction $s$ and the vertical reaction $S_1$. If the angle of incline is $i$, then $S_1 = S \cot i$. When the wheel is at rest, then the reaction $S_1$ is the only one which the weight of the wheel must overcome. But when the wheel is rotating, there is an additional vertical reaction to be overcome, which arises out of the friction between the flange and rail due to the normal pressure $s$. The contact point being at the distance $q$ ahead of the center of the wheel, the friction at this point would cause the wheel to tend to rotate about the bearing point, rising off the tread, so that some of the weight of the wheel is required to hold it down against this friction. This can be better understood by recalling that the wheel bears against the rail at an angle, causing it to nose into the rail and tending to make it roll up the inclined plane and go over the rail. This friction, due to the binding action, high bearing pressure and small area of contact, is very high, and its coefficient, $f'$, may safely be put at 0.35. The normal force

$$s = \frac{S}{\sin i},$$

and the friction is then $f's$. This friction then has the vertical component $s_1 = f's \sin i$. Therefore the vertical reaction which must be overcome by the weight on the wheel while rotating is $S_1 + s_1$.

**The factor of wheel bearing.**

The ratio of the weight on the wheel to the vertical thrust which tends to lift the wheel may be called the *factor of wheel bearing*. When this factor is equal to or greater than 1.00, the wheel will stay on the rail and when it is less than 1.00, the wheel will climb the rail. As soon as the flange gets on top of the rail, the factor of wheel bearing increases, but it is too late and the longitudinal rolling carries the wheel over. Sometimes after the leading driver has left the rail, the factor of wheel bearing of the second driver becomes sufficiently low to cause it also to climb over the rail, but such cases, while reported occasionally, are not nearly as common as derailments of the leading driver only. One would naturally suppose that when the first driver left the rail, the additional weight thrown upon the second driver would give it the necessary factor of wheel bearing to keep it on the track, which it does in most cases.

In order to illustrade the practical application of the analysis given above, let us consider the case of a Santa Fe type locomotive having the weights and dimensions given in figure 9. First find the actual weights on the rails under each wheel. Referring to figure 6 let $d = 60$ inches, which is the gage of the

track plus the width of one rail head plus the widening of the gage on the curve. Also let the height of the center of gravity of the locomotive be $h=96$ inches and the elevation of the outer rail be $e=4$ inches. Then, from the formula

$$e^1 = \frac{eh}{d}$$

we find the value of $e^1$ to be 6.4 inches. Then we may reduce the formulas

$$R = \frac{W\left(\frac{d}{2} - e^1\right)}{d} \quad \text{and} \quad R^1 = \frac{W\left(\frac{d}{2} + e^1\right)}{d}$$

to $R=0.393W$ and $R^1=0.607\,W$ for the outside and inside wheels respectively. Using these formulas and the weights given in figure 9, we obtain the following results :

| Location | Wheel | Lb. |
|---|---|---|
| Leading truck | Outer | 11 200 |
| | Inner | 17 300 |
| First driver | Outer | 22 165 |
| | Inner | 34 235 |
| Second driver | Outer | 21 969 |
| | Inner | 33 931 |
| Third driver | Outer | 23 816 |
| | Inner | 36 784 |
| Fourth driver | Outer | 23 501 |
| | Inner | 36 299 |
| Fifth driver | Outer | 23 698 |
| | Inner | 36 602 |
| Trailing truck | Outer | 22 990 |
| | Inner | 35 510 |

Considering the coefficient of friction between the wheel and the rail to be 0.20, and multiplying the above weights on the drivers by this factor, we obtain for the forces necessary to slide the wheels the following amounts :

| Driver | Outer wheel, lb. | Inner wheel, lb. |
|---|---|---|
| Front | 4 433 | 6 847 |
| Second | 4 394 | 6 786 |
| Third | 4 763 | ... |
| Fourth | 4 700 | 7 260 |
| Fifth | 4 470 | 7 320 |

Now suppose we have two trailing truck centering springs in tandem, each spring having an outer coil 8 inches in diameter of 1-inch round steel and nine coils and an inner coil 5 1/2 inches in diameter of 5/8-inch round steel and 15 coils. Also, let each spring have an initial compression of 4 inches and a further compression, due to curvature, of 2 inches, making a total of 6 inches. Thus for the outer coil, $d = 1$ inch, $r = 3.5$ inches, $n = 9$ inches and $F = 6$ inches; and for the inner coil $d = 5/8$ inch, $r = 2.44$ inches, $n = 15$ inches and $F = 6$ inches. Substituting these values in the formula

$$T = \frac{FGd^4}{64nr^3}$$

we obtain for the outer coil, $T=3\,037$ lb. and for the inner coil $T=821$ lb. The sum of these two, or 3 858 lb. is the load on the spring when compressed. If the angle $t=1°\ 30'$ then $T_1=T \cos t=0.9996$ $T=3\,856$ lb. This shows that the force $T_1$ may be considered equal to T for all practical purposes.

Suppose the drawbar pull to be the nominal figure of 30 000 lb. acting through a 2° angle. Its side thrust, then is $W_1 = W \tan 2° = 0.0349\,W = 1\,047$ lb.

Having calculated the resisting forces, let us next consider their moments. We obtain by solving right triangles, the values for the diagonal distances given in figure 9. Using these values, and those for the other forces given in figure 9, we obtain the moments :

| Driving wheel. | | In.-lb. |
|---|---|---|
| First outer | $146.82 \times 4\,433 =$ | 650 853 |
| Second outer | $89.94 \times 4\,394 =$ | 395 196 |
| Third outer | $60.00 \times 4\,763 =$ | 285 780 |
| Fourth outer | $89.94 \times 4\,700 =$ | 422 718 |
| Fifth outer | $146.82 \times 4\,740 =$ | 695 927 |
| First inner | $134.00 \times 6\,847 =$ | 917 498 |
| Second inner | $67.00 \times 6\,786 =$ | 454 662 |
| Fourth inner | $67.00 \times 7\,260 =$ | 486 420 |
| Fifth inner | $134.00 \times 7\,320 =$ | 980 880 |
| Trailing truck spring. | $305.00 \times 3\,856 =$ | 1 176 080 |
| Draw bar pull | $331.00 \times 1\,047 =$ | 346 557 |
| | Total resisting moment. . . | 6 812 571 |

The next step will be to evaluate the overcoming reactions. If the leading

truck weighs 3 500 lb., then the weight on the truck is 28 500 — 3 500 = 25 000 lb. Referring now to figure 7, if the distance from center to center of the rockers is 14 inches, and the lateral movement of the bolster due to curvature is 4 inches, then $r=3$ inches and $s=11$ inches. From the formulas

$$Z_1 = \frac{Zs}{r+s} \quad \text{and} \quad Z_2 = \frac{Zr}{r+s},$$

we find these reactions to be 19 643 lb. and 5 357 lb. on the outer and inner rockers respectively. The angle $z$ depends upon the design of the bolster, and is usually about 18°. The horizontal components of these vertical reactions are then $Y_1 = Z_1 \tan 18° = 19\,643 \times 0.3249 = 6\,382$ lb. and $Y_2 = Z_2 \tan 18° = 5\,357 \times 0.3249 = 1\,740$ lb. The total leading truck reaction is then $U = 6\,382 + 1\,740 = 8\,122$ lb., the lateral component of which is $U_1 = U \cos u$, which for a 1° 30′ angle gives $U_1 = 8\,122 \times 0.9996 = 8\,118$ lb., so that the effect of this angle may also be neglected in practice.

The reaction of the leading truck radius bar center pin may be computed from the formula

$$V = \frac{fOd}{a},$$

in which $f$ is the coefficient of friction, 0.20, O is the weight on the outer leading truck wheel, 11 200 lb., $d=60$ inches, as before and $a = 80$ inches, from figure 9. Then $V = 1\,680$ lb. and for a 1° 30′ angle $v$, its lateral component is $V_1 = V \cos v = 0.9996\ V = 1\,679$ lb., from which it may also be seen that the effect of this angle may be neglected in actual work.

The trailing truck radius bar center pin reaction may likewise be found from the formula

$$R = \frac{df O_6}{a^1},$$

in which $d=60$ inches as before, $f=0.20$,

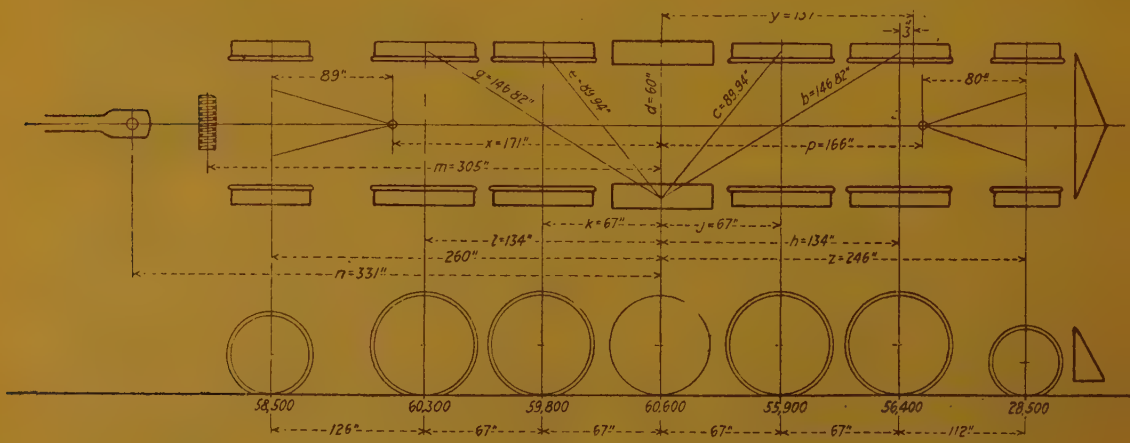


Fig. 9. — The wheel loads and dimensions of a typical Santa Fe type locomotive.

the weight on the outer wheel being $O_6 = 22\,990$ lb. and $a^1 = 89$ inches from figure 9. This gives $R = 3\,100$ lb. with its lateral component $R_1 = R \cos r$, which for a 1° 30′ angle gives $R_1 = 3\,100 \times 0.9996 = 3\,099$ lb. showing that in this case too, R may be taken for $R_1$.

Using the moment arms given for these

reactions in figure 9, we find the moments of these three reactions to be :

| | | In.-lb. |
|---|---|---|
| Leading truck pivot . . | 166 × 1 679 = | 278 714 |
| Leading truck . . . . . | 246 × 8 118 = | 2 098 028 |
| Trailing truck pivot . . | 171 × 3 099 = | 529 929 |
| Total of all moments. | | 2 906 671 |

The difference between this total moment and the total of the resisting moments must be taken care of by the flange of the leading driver, acting through the moment arm $y$, or 6 812 571 — 2 906 671 = 3 905 900 inch-pounds for the leading flange. If the point of contact between the flange and the rail of this driver is 3 inches ahead of the center of the wheel, then its moment arm is, referring to figure 9, 137 inches. Dividing the otherwise unbalanced moment of 3 905 900 inch-pounds by this arm gives 28 510 lb. as the thrust that must be produced by this flange.

Considering now the angle of incline, $i$, in figure 8 to be 80°, we find that the vertical component of this thrust of 28 510 lb. is $S_1 = S \cot i = 28\,510 \times 0.1763 = 5\,026$ lb. We also find that the pressure normal to the rail is

$$s = \frac{S}{\sin i} = \frac{28\,510}{0.9848} = 28\,950 \text{ lb.}$$

The vertical reaction of the friction due to this normal pressure is $s_1 = f^1 s \sin i = 0.35 \times 28\,950 \times 0.9848 = 9\,978$ lb. The sum of these two vertical reactions, or $5\,026 + 9\,978 = 15\,004$ lb., must be overbalanced by the weight on the wheel if a derailment is not to result. Referring to the above computation of weights on the various wheels, we find that the outside leading driver exerts a load of 22 165 lb. on the rail, which is sufficient to hold the wheel down.

The factor of wheel bearing in this case is $\frac{22\,165}{15\,004} = 1.47$, and as long as it is greater than 1.00, we do not need to fear trouble from the wheel climbing the rail. But 0.47 does not give very much of a margin and it is easy to see that it would not take very much variation in any one or more of the numerous conditions entering into this factor to bring it down to 1.00, or even lower, and thus cause a derailment. For example, a low joint may momentarily cause a reduction of weight on the leading driver-momentarily, yet just long enough to allow the wheel to climb the rail. A slight increase in elevation may do the same thing. A rail, out of line even for a short distance, may cause an added side thrust sufficient to do the trick. The locomotive may be just out of the shop, still somewhat stiff, and with the lateral taken up to the minimum, so that the binding action causes extra pressure and friction on the leading flange, the tires may still have their tool marks, which greatly increases the coefficient of friction. All of these factors tend to lower the wheel's advantage over the rail. These as well as many other conditions may be mentioned, which are contributory to the lowering of the factor of wheel bearing to the danger point of 1.00.

### Benefits derived from this study.

The value of a study such as this is not so much in setting forth the principles involved, or in being able to calculate actual forces and stresses, or even in being able sucessfully to investigate cases of derailments and find the causes thereof, as in being able to point out the conditions in the locomotive, track or operation which may be improved to prevent such derailments. The study is more of a means than an end in itself. So it would be well, in order to attain the desired end, to discuss some of the factors involved in the light of their effect on locomotive, track and operating conditions.

### Locomotive conditions.

Probably the locomotive condition which has the greatest effect in increas-

ing the factor of wheel bearing is the lubrication of the leading flange . This lubrication makes a marked decrease in the coefficient $f^1$ with a proportional decrease in the vertical reaction $S_1$. All modern heavy locomotives should have flange lubricators and in case of a derailment, the lubricators should be the first thing examined to see if they are working properly. Of next or nearly equal importance is the smoothness of the tire surface. We read of automobile tires that are geared to the road, and we get the same effect from locomotive tires that have finishing tool marks left on the tread due to chattering wheel lathes. A lathe should be powerful enough to take a finishing cut over the whole tread with a contour finishing tool without chattering. Of course tool marks soon wear off, yet the records show that many derailments take place with locomotives just out of the shop, on which the tires are not yet worn smooth. The pressure between the leading flange and the rail and its consequent vertical frictional and wedge reactions are not so great if the locomotive does not bind in the curve. There are several devices which may be employed to advantage in order to lessen or eliminate binding. The lateral or hub clearances may be increased on all the drivers or only on the front and rear hubs. This however, cannot be carried too far, on account of the I. C. C. limits for lateral, which require the wheels to be dropped, in case the lateral is too great. Yet the wear is greatest when the lateral is the least and even a little increase helps.

Setting the tires of the front and back wheels closer, back to back, than the others helps to lessen the binding. The use of blind tires on the main wheels, which has been assumed in this study, also helps. In addition to these remedies for binding there are other devices, such as floating axles, which could be considered to advantage. But when such devices are used, they require a slightly different treatment of the problem of finding the factor of wheel bearing, due to the changed method of guiding, increased overhang of the leading truck. etc. It may also be observed that the coning of the treads of driving wheels has an effect on the situation. The coning soon wears off, but while it lasts, it does not act the way it should. By referring to figure 4 it will be seen that since the axles are held parallel to the frame and not radial to the curve, the fourth and fifth drivers have their large diameters rolling on the inner rail and their small diameters rolling on the outer rail. This is just the opposite from what we would like to have with the result that the longitudinal slipping of the wheels is increased. The two leading drivers behave in the desired way, but since they are coupled to the others by the side rods, the effect of their good behavior is lost.

From the foregoing discussion, the benefit of the weight on the leading drivers and leading truck is apparent. These weights should be made as large as possible consistent with journal bearing pressures and rail loads. The driving wheel weight enters directly into the factor of wheel bearing and the leading truck weight enters directly into a guiding reaction which has a large moment arm and is therefore valuable. It may be observed from figure 7 and the discussion relating to it, that in curving an additional weight is thrown on the outer leading truck wheel, thus helping to increase its factor of wheel bearing and thus keep it on the rail. Sharp flanges are often blamed for derailments and sometimes justly, but in a case of this kind it would seem that they would be more advantageous than harmful. They increase the angle of the inclined plane between the flange and rail and thus lower the vertical force necessary to resist the side thrust. Long wheel bases, other things being equal, cause more binding in a given curve than short

ones. Whether they would cause an increase in the factor of wheel bearing is something that would have to be determined for each case; for the moment arms of the resisting forces increase, at the same time the moment arms of the guiding reactions also increase, and an investigation would have to made to determine if the one increased more than the other.

Mention has already been made of the resistance of the trailing trucks to curving, but these trucks become guiding trucks when backing, so that we can do no more than try to get a good compromise for the amount of their side thrust. The same is true of the leading trucks, except that the forward motion should be favored at the expense of the backward. While the effect of a booster on the trailing truck has not been taken into account in this study, such a device has a real bearing on the problem. For the traction of the booster has a lateral component which assists the curving of the locomotive by an outward thrust in forward motion.

### Track conditions.

The track condition having the most important bearing on the problem is probably the elevation of the outer rail. Each locomotive requires a certain particular elevation for each speed and curvature so that, at best, any given elevation is a compromise. And since heavy locomotives require little elevation at low speeds this becomes the operating problem of running these locomotives faster or the fast trains slower, or by making a compromise to the end that the elevation may be reduced consistent with safe operation of fast trains. The elevation operates at very slow speeds, as already shown, to relieve the outer rail of weight and to place it on the inner rail. Or, in the case given, the outer leading wheel carries 22 165 lb. and the inner leading wheel, 34 235 lb. for a four-inch elevation. Now if the elevation was increased so that the outer load of 22 165 lb. were reduced to 17 147 lb., which was found to be the vertical reaction, there would be nothing to prevent the wheel from climbing over the rail. Thus we see that rail elevation is a direct factor in the problem.

Next to elevation comes the matter of curve-worn rail. The worn surface simply provides the inclined plane up which the flange, if not restrained by weight, rolls to freedom. The more curve-worn the rail, the easier the ascent and the more difficult the work of holding the wheel down.

It would seem from this study that the track gage has little bearing on the problem, provided it is great enough to prevent binding, and in order to do this for Santa Fe type locomotives, it must be a little wider than standard on curves of eight degrees or more. Mention has already been made of track surface and alinement, and of the fact that variations in these, as well as in elevation, may cause momentary disturbances in the balance of forces sufficient to cause a derailment. The general use of spiral curves is helping to relieve locomotives of the sudden side thrust when entering a curve with the consequent sudden lowering of the factor of wheel bearing, thus making for the safer operation of heavy locomotives.

### Operating conditions.

While it has already been stated that any locomotive should be able to be operated at any reasonable speed over any curvature for which it is suitable, and that the locomotive and track conditions should be altered if necessary to make operation safe, yet it is profitable to see what effect operating conditions actually do have on the curving of locomotives. For example, it may be difficult to persuade a locomotive engineman to « widen on her » on a curve where

he may have been on the ground the trip before, yet we must conclude from the study of the problem that an increase in speed helps reduce derailments, for not only does the coefficient of friction decrease with the speed, but also the effect of centrifugal force begins to be felt in helping to hold the outer wheel down. This deduction is borne out in practice. Locomotives that derailed at a particular place and a certain speed were found to traverse the place safely when the speed was increased. The use of steam and brakes also has some effect, for it has been found that locomotives will sometimes drift around a curve when, at slow speeds, the use of either steam or brakes would cause the wheels to tend to line up against the lateral, apparently increasing the binding and friction. Reference has already been made to the beneficial use of the booster on curves, the use of steam just mentioned not being intended to apply in the case of the booster. Reference has also been made to the reduction of the elevation which may be permitted by decreasing the speed of high-speed trains on curves that are giving trouble with heavy low-speed locomotives.

### Summary

In order to grasp the situation as a whole, let us summarize the conditions which make curving easier and derailments fewer. In making changes, each of these conditions should be considered in the light of other related conditions, and the changes made should always be consistent with safety of operation and economical maintenance. These conditions are :

*In the locomotive :*

Flange lubrication.
Smooth tire and flange surfaces.
Increase in hub clearance.
Decrease in gage spacing of tires.
Use of blind tires on main drivers.
Use of floating axles.
Decrease in coning of wheel treads.
Increase of weight on the leading drivers and engine truck.
Decrease of the trailing truck's side thrust.
Increase of leading truck side thrust.

*In the track :*

Decrease of the elevation of the outer rail consistent with the safety of high-speed trains.
Removal of curve-worn rails.
Maintenance of good service.
Maintenance of good alinement.
Widening of the gage on curves to prevent binding.

*In operation :*

Judicious use of speed on curves.
Drifting around curves.
Use of booster on curves.
Reduction in speed of high-speed trains to permit some elevation to be taken out of the track.

This method of analysis may also be used for the investigation of the factor of wheel bearing of the leading truck by assigning a calculated value to the side thrust of the leading driver and solving for the vertical reaction of the leading outside truck wheel. It may likewise be used for the investigation of derailments of either drivers or trailing truck wheels when the locomotive is running backward.

# MISCELLANEOUS INFORMATION

[ 625 .143.3 (.73) ]

## 1. — Relative wear on guarded and unguarded curves.

By James F. BURNS,

ASSISTANT ENGINEER MAINTENANCE OF WAY, LOUISVILLE & NASHVILLE RAILROAD.

Figs. 1 and 2, p. 2572.

(*Railway Review.*)

The *Railway Review* of 30 August 1924, contained a description of the Maney guard rail which is being used quite extensively on the Louisville & Nashville and other railroads. In that article a diagram was given which showed the amount of rail wear on an unguarded 10-degree curve, and another showing the wear on a curve of the same radius, under identical traffic and maintenance conditions, but which was protected by this guard rail. The diagram in question showed the comparative wear on the two curves after seven months' severe service under a tonnage movement ranging from 30 000 to 75 000 tons per day.

The accompanying diagrams show the comparative wear of 100 lb. R. E. rail after ten month's service, both with and without the guard rail. The measurements from which the diagrams were made, were taken 6 August 1924. Shortly after the measurements were made the high rail of the unprotected curve was removed on account of excessive wear.

In September 1924, traffic conditions over this rail were greatly changed. Up to that time this line was single track and the rail from which the diagrams were made bore both the heavy north bound coal tonnage, the volume of which is indicated above, and in addition, the lighter empty tonnage moving south bound. When the second track was put into operation in September, the original track became the south bound main track, and now carries only the empty car movement. For this reason traffic over the rail is not as heavy since the measurements were taken as it was before. On 6 February 1925, a new set of measurements was made on the curve protected by the guard rail, with the following results :

No additional wear could be detected on either the high or low rail at station 1 of the diagram. At station 2 there was no additional wear on the high rail; additional wear amounting from 1/64 to 1/32 of an inch was found on the low rail. At station 3 no additional wear was found on the outer rail of the curve, but on the inner rail the wear was identical with that found at station 2. At station 4 the outside rail showed no additional wear and the inner only 1/64 of an inch.

From the time the rail was originally laid on this curve until the measurements shown in the diagram were taken, the daily traffic consisted of from 800 to 1 000 loads of coal per day north bound and an equal number of empties south bound. The diagram shows the wear under ten months of such traffic. But, as stated, since the double track operation was commenced the movement over the rail from which the diagrams were made consists of approximately 1 000 empties per day. This traffic has caused no additional wear which can be detected on the outer rail of the curve, and the additional wear on the inside rail was found to be a maximum of 1/32 of an inch.

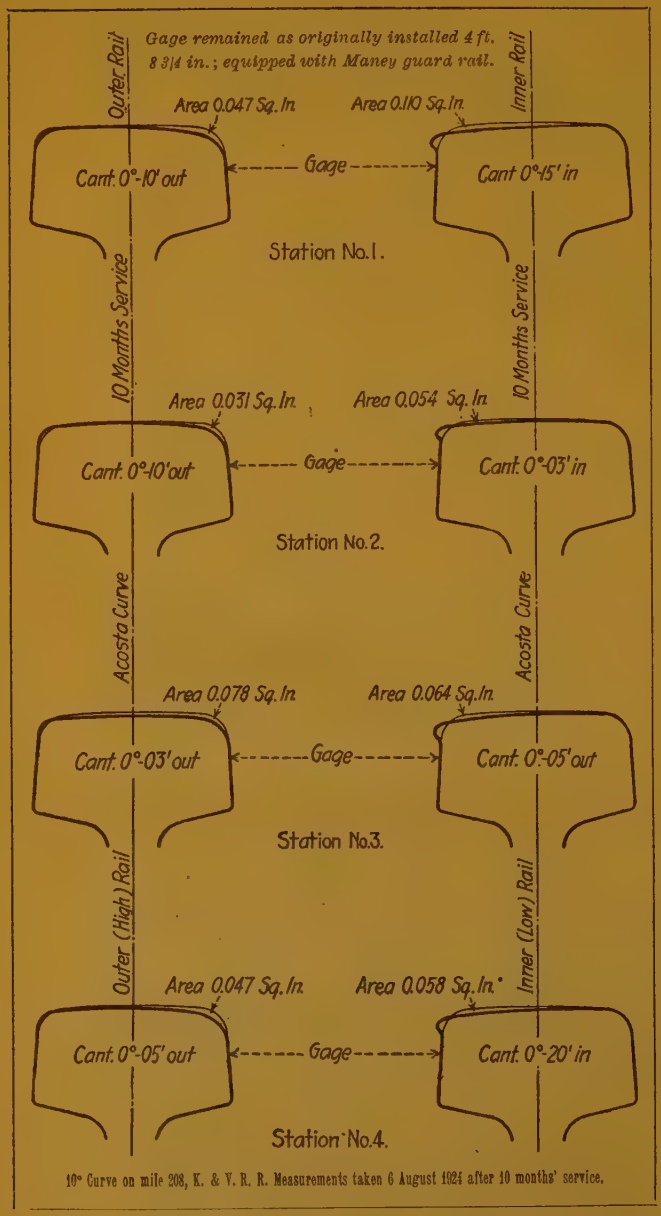


Fig. 1. — Rail wear, after 10 months' service, on curve equipped with Maney guard rail.

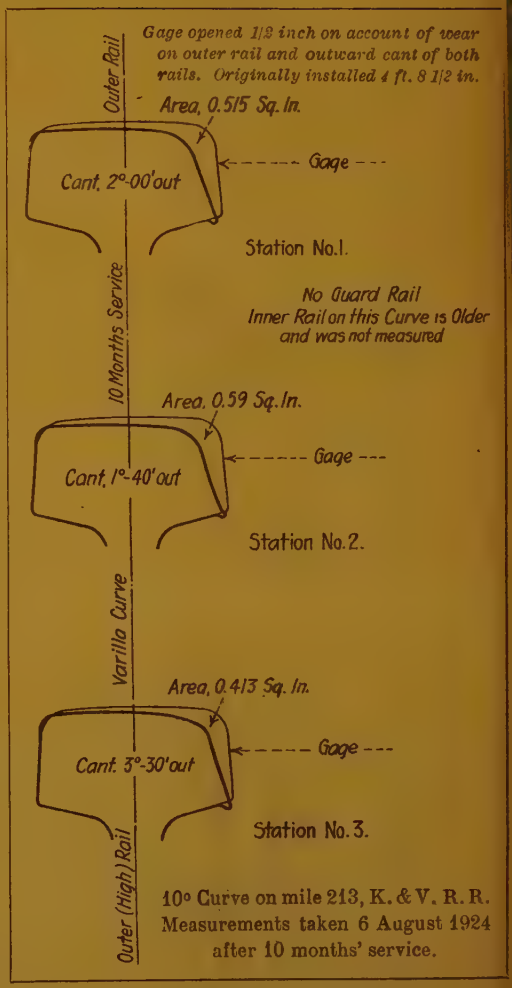
Gage opened 1/2 inch on account of wear on outer rail and outward cant of both rails. Originally installed 4 ft. 8 1/2 in.
Outer Rail
Area, 0.515 Sq. In.
Gage
Cant. 2°-00' out
Station No. 1.
No Guard Rail
Inner Rail on this Curve is Older and was not measured
10 Months Service
Area, 0.59 Sq. In.
Gage
Cant. 1°-40' out
Station No. 2.
Varilla Curve
Area, 0.413 Sq. In.
Gage
Cant. 3°-30' out
Station No. 3.
Outer (High) Rail
10° Curve on mile 213, K. & V. R. R. Measurements taken 6 August 1924 after 10 months' service.

Fig. 2. — Rail wear on unguarded curve, after 10 months' service.

686. 211.5 (.73) ]

## 2, — A new type of train shed.

(Abstract of a paper, by WALTER S. LACHER.)

Figs. 3 to 5, p. 2574 and 2575.

(*Railway Age.*)

One of the outstanding features in the design of the passenger terminal at Chicago is a new type of train shed which represents a development resulting from the unusual conditions imposed by the arrangement of the platforms and a sincere effort to effect an improvement over previous designs. It was desired to provide a low type of shed and because the open umbrella or butterfly sheds do not afford complete protection against rain or snow it was concluded that the shed must be of the enclosed type with smoke slots just clearing the locomotive stacks to obtain an immediate discharge of smoke into the open air. It was also felt desirable to provide more headroom over the passenger platforms than is usually obtained in low sheds. Another controlling consideration in the determination of the design was the width of the baggage platforms which is not sufficient to permit the placing of any columns in them. Consequently, the design had to be one in which the transverse roof span equals the distance between columns placed in the centers of the passenger platforms, or 49 ft. 9 in., a condition that at once introduced a serious problem to avoid excessively heavy and deep transverse girders to support the roof load.

These problems were solved by the development of a design which is not only ingenious from the standpoint of the structural engineer but is also unusually pleasing in appearance. The transverse load-carrying member comprises a flat arch girder affording a clearance of 17 feet from top of rail, combined with two upward extending legs which are carried to a connection at the column at a height of 28 feet above the platform. This arrangement provides a heart-shaped truss over each column which performs two important functions. It provides a monitor over the passenger platform affording the desired headroom, more effective lighting and better ventilation, and it effects a marked shortening of the effective span of the transverse girders.

For the purpose of reducing the obstruction in the passenger platform resulting from the presence of the shed columns, they were spaced as far apart as practical considerations would permit, 41 ft. 8 in. center to center. The load between the transverse frames is carried very largely on the longitudinal girders forming the sides of the smoke slots, but supplemented by arch girders in the planes of the columns which frame into two struts connecting with the tops of the columns to form a ridge pole for the monitors over the passenger platforms. These longitudinal members support five equally spaced rafters conforming to the contour of the roof outline to provide the primary support for the roof covering. Particular commendation must be made of the manner in which the detailing and fabrication of the train shed frames were carried out. The frames have an exceptionally neat, graceful and finished appearance, one means to this end being the use of special sections of bulb beams for the curved rafters.

No less distinctive than the outline and framing of the shed is the roof covering which consists of Federal cement tile throughout, for the profile of the roof cross section is such as to call for the exercise of ingenuity as well as accurate workmanship to provide precast tile that would insure a perfect fit to the curves and angles of the steel frame. It imposed the necessity of providing 11 varieties of tile units for the standard portion of the shed and special units used in the portion of the shed near the outer ends where it conforms to the curves of the converging tracks and where the sheds adjoin the street viaducts.

The top of the high monitor over the passenger platform has a ventilating hood which

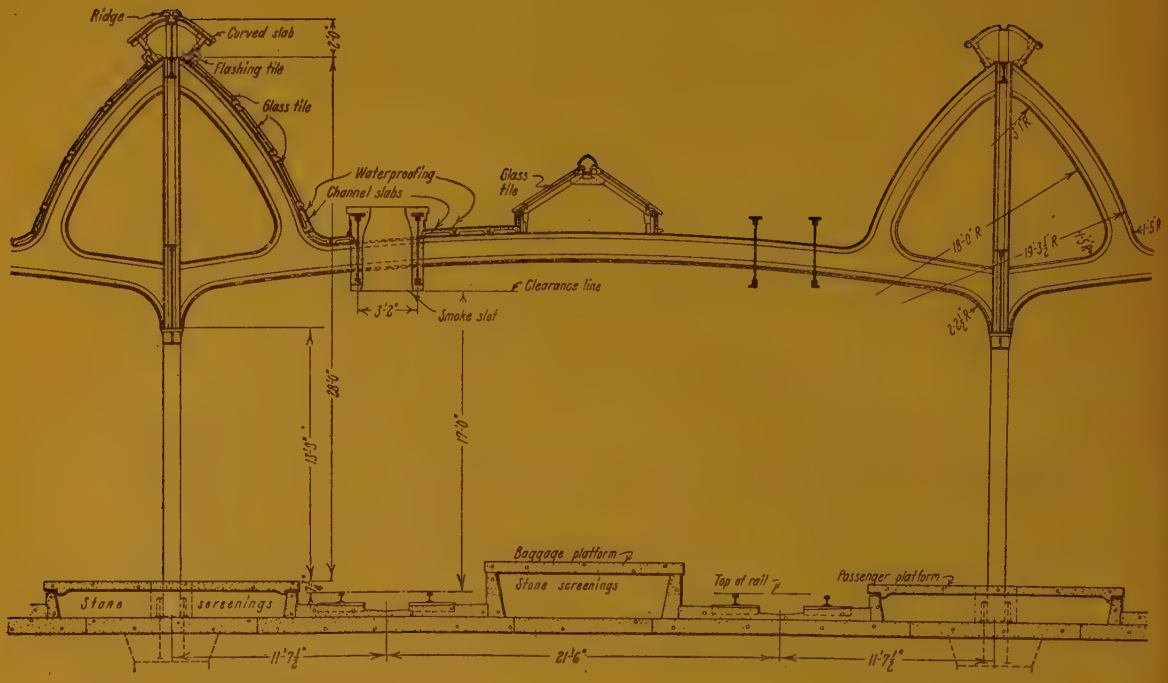


Fig. 3. — A typical cross section of the train shed, station tracks and platforms.

Fig. 4. — The concrete tile and glass units were made to fit accurately to the steel frame of the train sheds.

is covered by two curved slabs 1 1/4 inches thick, 24 inches wide and 36 inches long measured on the curve of this hood, with a special cap unit covering the joint at the ridge. The sides of the monitor for a width of about nine feet serve as continuous skylights and are covered with three tiers of curved glass tile 1 1/8 inches thick, 24 inches wide and 36 inches long, each of which contains a pane of 1/4-inch rough wire glass, 20 inches by 30 inches.

Over each baggage platform is a gable type skylight covered with interlocking tile 1 1/8 inches thick, 24 inches wide and 52 inches long on each slope with a standard ridge cap at the ridge. Each third interlocking tile on both slopes is provided with a pane of glass

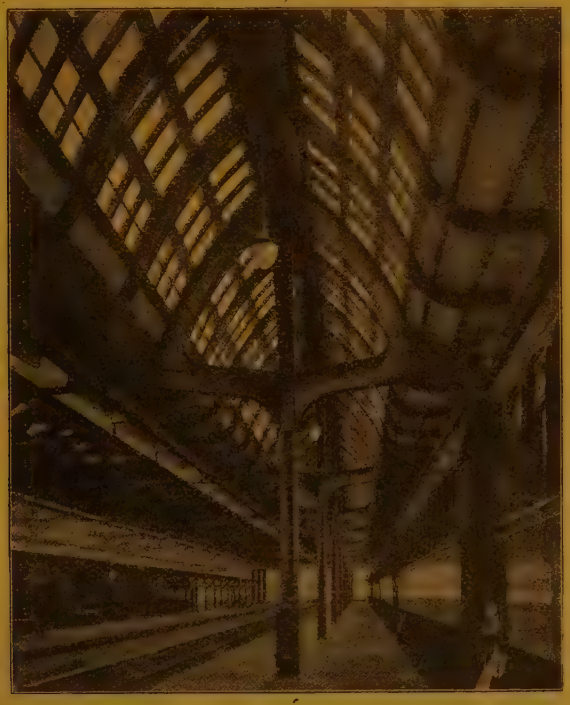

Fig. 5. — The train shed is of a design which affords ample light and air over the passenger platforms.

21 inches by 35 inches. The remaining portion of the shed roof, namely between the baggage platform skylights and the lower edge of the passenger monitor skylights exclusive of the smoke slot is covered with channel-section slabs approximately 18 inches wide by 8 feet long. In addition to these units flashing tile are provided under the edges of the baggage skylight and under the hood over the passenger monitor.

The channel slabs form gutters which provide the drainage for the roof, emptying into down spouts at the low end of each block. The gutters are provided with Johns-Manville built-up roofing which is flashed up under the skylight and up the sides of the smoke slots. All the rest of the tile are uncovered, as water proof construction is insured by overlapping horizontal joints and filled vertical joints, together with the density of the concrete in

the slabs themselves. The plastic joints are formed by projecting lips on the vertical edges of the slabs, so shaped as to provide a groove which is filled with a special oil-cement filler covered with a weather coating of elastic compound. The glass tiles are of particular interest because the glass is concreted into the slabs in manufacture and is protected against stresses set up by changes in temperature, wind pressure and other strains by dipping the edges of the glass in a hot asphalt preparation before inserting it into the concrete.

Another difficulty imposed in the construction of the train sheds was introduced in the provision for a covering for the girders of the smoke slots to protect them from the corrosive locomotive gasses. Poured-in-place concrete was used for this purpose, the particular problem being to insure a high density in a concrete of such consistency that it would readily flow around the reinforcement and in an exceedingly narrow space between the forms and the sides of the girders. To obtain this the mixture was designed according to the Abrams method.

[ 621 .335 (.73) ]

### 3. — Locomotives for the Ford Railway electrification.

The *Railway Review* for the 18 October 1924 describes the railway stock which Mr. Ford proposes to use for the electrification of a part of his railway. In accordance with the information which we have received, the system adopted differs radically from that adopted by other railway companies in their electrification schemes. We shall have occasion in the future to describe all the details of this arrangement, meanwhile it may be of interest to mention the following points :

Power is supplied to the locomotive as single-phase current at 22 000 volts, 25 periods. Each motor unit will carry a 2 000 kv. a. transformer, reducing the voltage to 1 250; moreover, it will be fitted with a motor generator set consisting of a single-phase motor of 2 100 H. P. and a continuous current generator of 1 500 kw. (2 500 amperes, 600 volts and 750 revolutions per minute). The traction motors will be of 225 H. P.; they will each be connected to a driving axle by double gear wheels situated at both ends of the armature shaft, the gear ratio being 22/98. The maximum speed will be 17 miles per hour. For starting the motor generator each motor unit will carry a 60 cell battery of accumulators.

E. U.

[ 621 .337 (.494) ]

### 4. — One-man control for electric locomotives.

Figs. 6 and 7, p. 2577.

(*Railway Gazette.*)

The accompanying drawing (fig. 6) shows a new safety device recently developed by the firm of Brown, Boveri & Co. for use on electric locomotives with one-man control. This differs in certain respects from the various appliances of the « deadman's handle » type hitherto employed. It operates only when the locomotive is in motion, and even then only after the latter has covered a certain distance which can be regulated as desired. The action of the device commences after the driver releases his hold of a push-button or similar small switch. He does not require to keep it depressed, however, in the case of short shunting periods or when the locomotive is at rest. Further, there is the advantage that the push-button can be released for a few seconds at a time during running, without the supply of

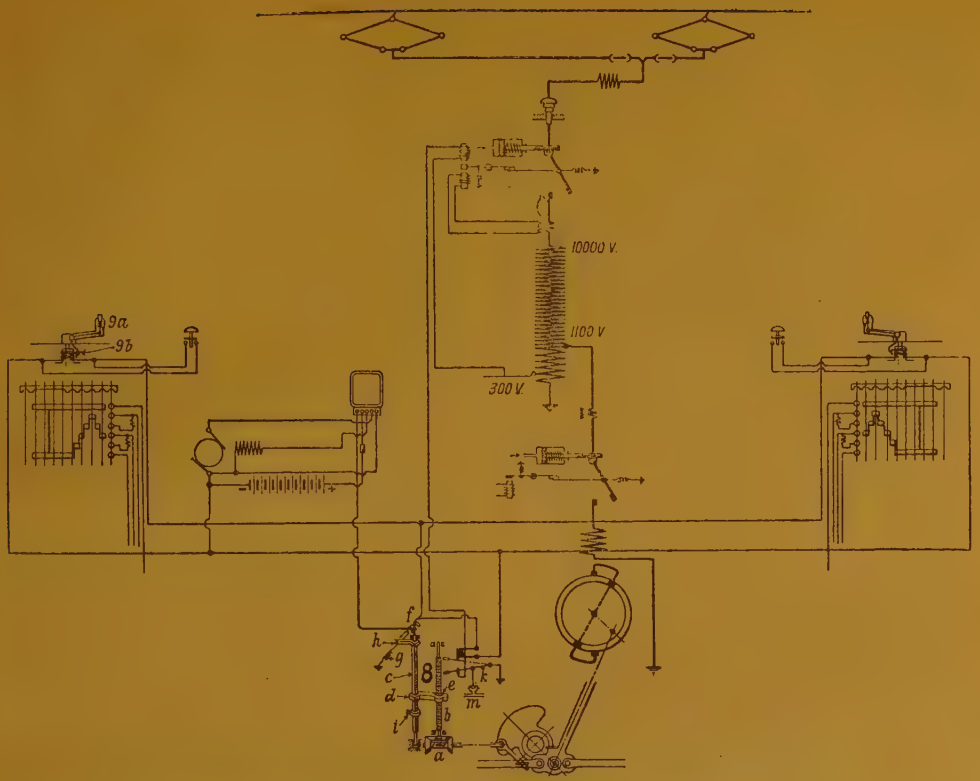


Fig. 6. — Diagram of connections and gear.

Fig. 7. — Detail view of apparatus.

current being cut off or the brakes applied. Under certain circumstances this helps to lighten the duty of the driver. Since it is possible to arrange for a very small distance (*e. g.*, 100 or 50 m. [110 or 55 yards] or even less according to local conditions) to be covered between the time the driver lets go the push-button and the moment when the savety device begins to operate, and as the braking effect produced is very strong, there is no risk of the train running past stopping places or signals set at danger.

The patent safety device consists of the releasing gear and the actuating apparatus. The former is operated from the driving mechanism and mounted either inside the locomotive or on the outside of the frame, and the latter comprises two push-buttons or similar devices situated in each driver's cab. These push-buttons are so arranged that the driver has to make no unnecessary movement to actuate them. He is within reach of at least one, no matter where he has to stand when controlling the locomotive. For example, one of the push-buttons can be fitted on or near the main control handle, so that it can be held down easily during the running period, while the other push-button is mounted so that the driver can operate it without difficulty while leaning out of the window when shunting.

The releasing gear consists principally of a vertical screw spindle rotated by the driving mechanism of the locomotive all the time the latter is running, and with which a suitably shaped nut can be brought into gear. This nut moves a certain adjustable distance up the screw spindle and, at the end of its travel, releases the main circuit breaker of the locomotive, at the same time setting the compressed air or vacuum brake in operation.

The manner in which the safety device works can be easily followed from the diagram. The screw spindle 8*b* is driven from the coupling rod of the locomotive through link mechanism and the bevel wheels 8*a*. The nut 8*e* forms part of an arm 8*d* and is brought into contact with the screw spindle by rotation of the square shaft 8*c*, upon which the arm can slide. When the driver lets go his hold of the control handle, contact 9*b* opens automatically and bréaks the circuit of the electro-magnet 8*f*. The square shaft then rotates in an anticlockwise direction under the action of the spring 8*g*, bringing the nut into mesh with the screw spindle, which causes the arm to move upwards as described. The lower position of the nut can be adjusted by means of the collar 8*i* on the square shaft. At the upper end of its normal travel, the nut actuates the lever 8*k*, which opens a contact interrupting the circuit of the no-volt coil of the main circuit breaker, and also the valve 8*m*, which causes the brakes of the locomotive to be applied. If the locomotive has not come to a standstill when the nut has reached the upper end of the spindle, the lever 8*k* closes a further contact, which again completes the circuit of the magnet 8*f*, so that the lever 8*h* is pulled against the tension of the spring, and the nut thus brought out of gear with the spindle. The nut arm then falls back on to the collar 8*i*. The scope of this latter device is to prevent the brake valve from being kept open after the full stop of the train; otherwise the driver would be obliged to catch hold of the handle 9*a* and to depress its button before being able to release the brakes.

The period that elapses between the releasing of the control handle, and the moment when the main circuit breaker is opened and the brakes actuated, can be adjusted by shifting the collar mentioned. When the travelling speed is low, it takes a longer time for the desired effect to be produced, but the distance covered remains the same. The nut commences to move upwards on the spindle as soon as the driver lets go the control handle; it will, however, be immediately pulled out of gear with the spindle and fall back to its lower position if the driver again takes hold of the handle within a fairly short time.

The device has been applied to some locomotives working on the Rhaetian Railway, Switzerland.

[ 625 .216 (.52) ]

## 5. — Automatic couplings on Japanese railways.

(*Railway Gazette.*)

The long-projected plan of equipping rolling stock on the Japanese Railways with automatic couplings was carried out on 17 July last, the actual work of transition being performed in the course of a single day. The rolling stock dealt with was 3 200 locomotives, 8 900 passenger cars and 52 000 freight vehicles.

Over 5 000 vehicles belonging to the private railway companies were also changed on the same day. About 12 000 workmen were engaged on the work. The first proposal for the change of couplers in Japan was made at a conference in 1913, a few years after the nationalisation of railways, and it was decided, in 1918, that the Japanese Government Railways should effect the change. Preparatory work was started in 1919 by constructing new cars, so that it might be easy to change couplers.

### *Railways previously using automatic couplings.*

Previously, automatic couplings were only used, among the railways under Japanese jurisdiction, on the railways of Taiwan (Formosa), Chosen (Korea) and South Manchuria. They had adopted automatic couplings from the beginning of the construction of their railways. In Japan proper, automatic couplings had been used on Hokkaido lines of 1 300 miles, and on the Tokyo suburban tramway lines for some ten years. Screw and link couplings and side buffers had been used by the Japanese Railways since the first rail was laid on Japanese soil by British engineers in the year of 1872.

When the Nationalisation of Railways Act was promulgated in 1906 and 17 private railway companies were bought by the Government, several different couplers were used on the rolling stock. The amalgamation of railways into one big system necessitated the unification of couplers and a standard type of screw coupler was formulated, and was in use until they were replaced with the automatics in July.

When the Government Railways of Japan decided to equip the stock with automatic couplings, they conducted investigations on the Hokkaido lines, and found that the American type couplers were quite satisfactory. They therefore decided to adopt this type on the whole of the lines of the Japanese Railways, at an expenditure of about 26 900 000 yen, spread over seven years. The Government also paid 1 500 000 yen, as subsidy, to the private railway companies, this being about half their expenditure.

### *Three stages of preparation.*

The authorities having come to the conclusion that it was far better to change the coupling equipment of all rolling stock in a very short time than to change them gradually, the necessary work of preparation was carried on while the old couplers were still on the cars. This work of preparation was carried out in three stages. The first stage was the remodelling of buffer beams of both ends of the vehicles and attaching follower guides to the centre sills. In the second stage, automatic couplers were allotted to all goods cars running and distributed over the whole lines. These couplers were hung crossways with draught spring to the body of a car under the centre sills when they came into workshops for repairing. Uncoupling levers were also attached to the proper position. Locomotives and carriages, however, were excepted from this work, because locomotives and carriages run between definite terminals, while they are usually laid aside for a few hours at the terminal before they leave it as a new train. It was, therefore, quite reasonable to change their couplers at terminal stations. In the case of goods cars, however, it was entirely different.

In the third stage of preparation, the testing and inspection of the work done in the first and second stages were performed. The operation was to take off the old couplers and buffers and then apply the hanging automatic couplers. After this was done couplers and buffers were re-attached in place and new couplers hung again under the centre sills. This work was done not only for inspection and testing, but also for practising the actual replacement.

*The work of replacement.*

The operations of replacing the old couplers was carried out on 17 July on the lines of Honshu and Shikoku, with the exception of the Tokushima line, which is very short and isolated from other lines. The work on the lines in Kyushu, a separated island from Honshu, was done on the 20th. The freight traffic over the whole system was completely stopped for an entire day, for 24 hours from the midnight of 16 July to the midnight of 17 July. A few special freight trains, however, were run for the purpose of carrying fresh fish, vegetables, etc. The regular freight trains being suspended, all cars were gathered to 221 stations in the course of the night. Parties, each consisting of six or eight artisans, were assigned to replace the couplers, from 20 to 25 cars being assigned to each gang, that is, about 3.5 cars to each person. The operation was to begin at 5 a. m. one day and be finished by 7 a. m. next day, but at some stations the replacement was practically finished at noon.

The couplers of passenger carriages were replaced from 1 July to 10, couplers at both ends of the trains being excepted. The replacing of couplers on both ends of the train and on the locomotives was carried out in a couple of hours between 16 and 17 July, while they were laid aside for a few hours at the terminals. The passenger traffic service on the 16th and 17th was thus carried on quite regularly and as smoothly as usual.

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[ 656 .212.6 (.73) ]

## 6. — Car dumper for transfer from narrow to standard gage cars on the Denver and Rio Grande Western.

Figs. 8 to 10, pp. 2581 to 2582.

(*Railway Age.*)

Among improvements recently completed on the Denver & Rio Grande Western is the installation of a rolling car dumper at Salida, Colo., to transfer coal, ore and other bulk materials from narrow-gage to standard-gage cars. Salida is the point of contact between the narrow-gage lines of the system extending into southern and western Colorado with the main standard-gage line between Denver and Salt Lake City. Owing to the difference in the gages, interchange of traffic at this junction requires the extensive transfer of lading from narrow-gage to standard-gage cars or vice versa. The great bulk of the railway's business calling for transfer originates on the narrow-gage lines and consists mostly of coal and ore. These two commodities constitute about 85 % of the transfer business and such bulk commodities naturally lend themselves readily to transfer by mechanical means, as with the use of a car dumper.

The machine consists of a cradle comprising a floor system supported by two structural steel rings upon which narrow-gage cars are spotted for dumping. This cradle rolls on an inclined track to the dumping position over a standard-gage track. This movement is effected by the aid of two cables fastened around the rims of the two circular girders and carried over sheaves at the top of two auxiliary towers, thence down to motor driven hoisting equipment in a hoist-house located between the bases of these two towers. As the rolling operation takes place the top of the car is

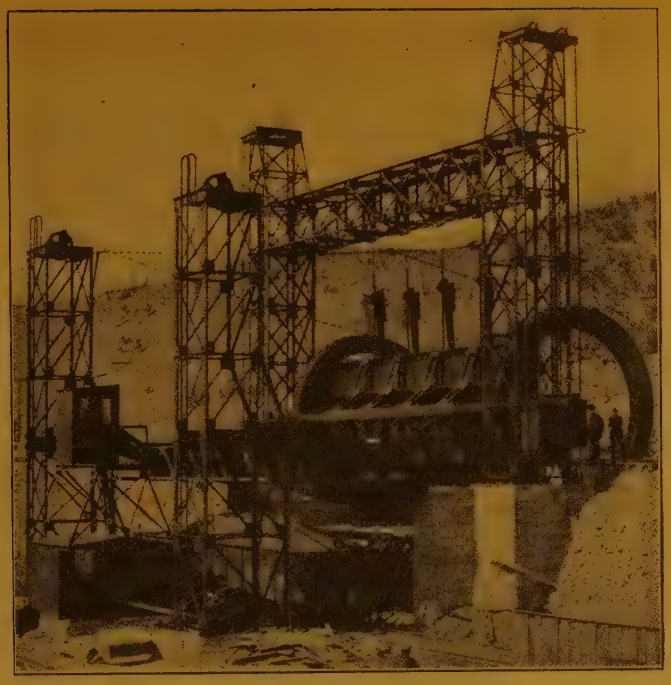

Fig. 8. — The car dumper as seen from the standard gage side. Hoist house and towers in the foreground.

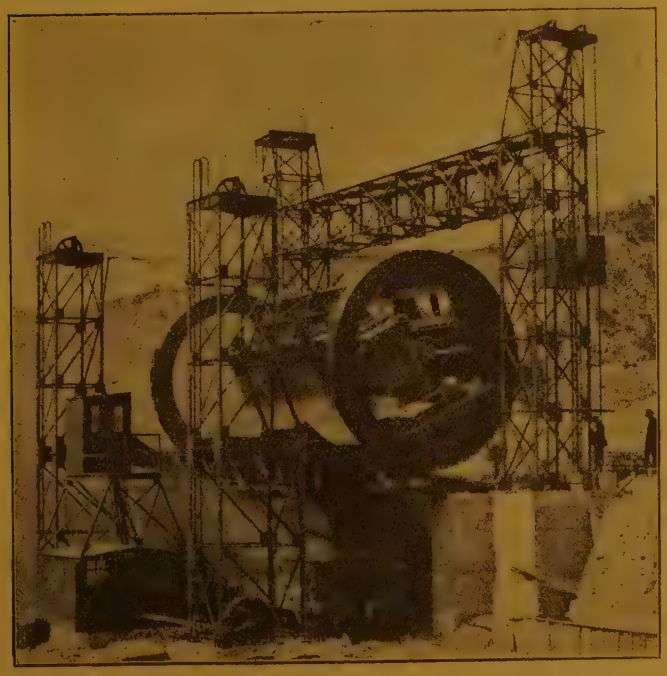

Fig. 9. — The dumper in operation. Clamp counterweights part way up the towers.

engaged by four clamps which support the car when in the inverted position. One end of each of these clamps is attached to the dumping frame while the other end is connected by means of a cable to one of four counterweights supported from sheaves at the tops of the two main towers. These four counterweights are clearly shown in the illustrations. The operation of the car dumper is effectively safeguarded by automatic control equipment.

The narrow-gage loads and the standard-gage empties are set by a switch engine on two gravity tracks and dropped down, one by one, to the machine. As the smaller cars are dumped and the larger cars are loaded they are moved by gravity to the delivery ends of the tracks where they are picked up by the yard engine to be placed in trains. The capacity of the gravity tracks is approximately 70 cars. The operation of the car dumper

Fig. 10. — A view from the upper or narrow-gage side.

requires five men, one to operate the dumper and four to move and spot the cars. These five men replace 75 men formerly employed in the manual transfer of materials from the narrow-gage to the standard-gage cars. With hand labor it cost an average of 23 cents per ton for all commodities handled in transfer, while during August 1924, a fairly heavy month, the cost of making the transfer by means of a car dumper averaged four cents per ton. Including the cost of transferring materials that could not be handled by the dumper, the general average cost of transferring at Salida during that month was 10.3 cents per ton. During the months of June, July, August and September, the car dumper was used for the transfer of 111 788 tons from narrow-gage to standard-gage cars with a saving in labor of $11 910.

The advantages derived from the installa-

tion of the car dumper are not restricted to the saving effected in the handling cost since one of the most important items is the marked decrease in the detention of cars while awaiting transfer. The car dumper will readily handle 20 cars per hour, whereas 75 men transferring by hand averaged about 30 cars per day. Furthermore, during periods when narrow-gage cars delivered to Salida exceeded this number, they were frequently detained from two to six days awaiting transfer, whereas they are now ready for the return movement within two hours after they are spotted on the dumper receiving track. Another source of economy in the new plant is derived from the reduction in yard switching service since none is now required from the time that the cars are set at the dumper until they are pulled out for the make-up of outbound trains. The equipment has now been in service eighteen months and has proved entirely satisfactory.

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[ 625 .213 (.73) & 625 .215 (.73) ]

## 7. — Friction bolster cushion of novel design.

Figs 11 to 13, p. 2584.

(*Railway Review.*)

The Frost Railway Supply Company of Detroit, Mich., presents to the railroads a new truck bolster cushion to take the place of the load carrying springs now in general use. The device is original and consists of a number of spring steel plates, cambered to take the load without a permanent set (figs. 12 and 13). It is made to interchange with the ordinary nests of springs so that no change in the present design or standard is necessary.

The Harvey friction truck bolster cushion consists of a top and a bottom malleable iron casting and a multiple of concave and convex spring steel plates. The top and bottom castings or caps have their surfaces sloping from the center out, the top cap having a concave and the bottom cap a convex surface. Each spring steel plate is cut out along its center axis into two sections connected by a narrow neck of metal. This neck or center portion of each plate is bent to give the two sections the same angle to the horizontal as that of the top and bottom caps.

The caps and plates are held together by long pins; when the load comes on the cushion and the upper cap moves down, the lower heads of the pins move down in pockets that are provided in the lower cushion cap. Only the ends of each pair of cushion plates are in contact on each side of the cushion. While each set of plates is in contact with the next set at the center, the top and bottom set of plates are in contact at the center with the top and bottom casting.

Thus, it will be seen that a load on the cushion causes each set or pair of plates to bend together. This movement makes the ends of each pair of plates slide on each other. The friction between the two plates that make up each pair of plates is sufficient to produce several hundred foot pounds of absorption when the cushion is compressed and released, and this absorption is sufficient to reduce the rocking of the car.

The rocking of a car is very pronounced with trucks equipped with helical springs and often causes the truck bolster to move up and down in the side frame to the full capacity of the springs. In road tests made on the Harvey cushion the maximum movement of the bolster up and down in the side frame was less than 3/8-inch, which indicates that the rocking of the cars was very much reduced. In fact observers watching cars in the same train equipped with the ordinary style of truck springs and those equipped with the Harvey friction bolster cushion were able to pick out the cars equipped with the Harvey cushion at first glance, due to the steadiness with which these cars went over the track.

The cushions are made in sizes for 50-ton cars and under, and for 55-ton cars and over. They have given satisfactory service under tenders.

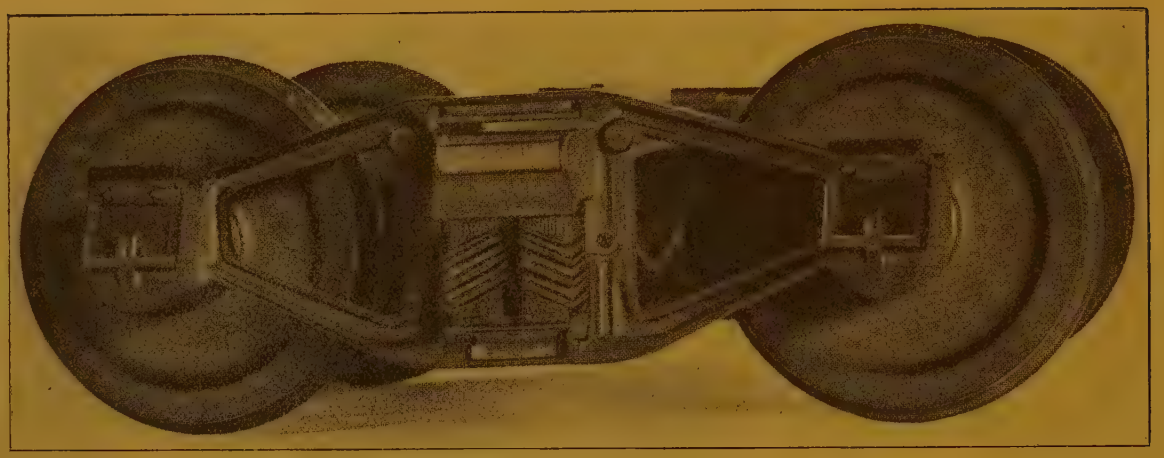

Fig. 11. — Illustration showing the application of the Harvey friction bolster cushion to a freight car truck.

Fig. 12. — The Harvey friction bolster cushion assembled to take the place of the nests of truck springs ordinarily used.

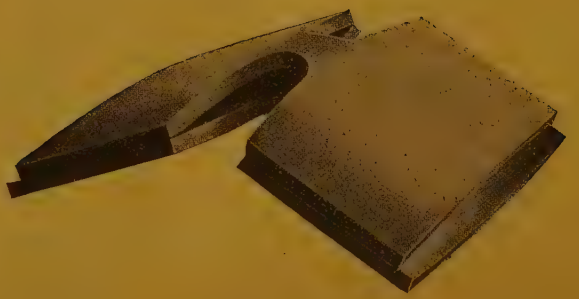

Fig. 13. — Detail of the friction plates showing the camber.

# NEW BOOKS AND PUBLICATIONS

[ 351. 812 (.44) ]

VASSEUR (L.), civil engineer. — **Les chemins de fer d'intérêt local, tramways et services publics automobiles** (législation et réglementation). — **Local railways, tramways and public motor bus services** (rules and regulations). — One volume 8vo (9 × 6 inches) of 729 pages. — 1923, Baillière & Sons, publishers, 19, rue Hautefeuille, Paris. — Price bound : 50 francs.

Mr. Vasseur's work may well be read and consulted by all those who have to deal with the existing laws in France concerning tramways, local railways and public motor bus services. In it will be found, besides expert opinion on these laws and regulations, certain very interesting articles dealing especially with : 1) in chapter IV, the various methods which have been used in France as a result of the work of Messrs. Considère, Colson, Picard, etc., to determine (for the purposes of relationship of the concessionnaires, or of those employed in working the concerns, with the public authorities granting the concession or with the proprietors) the estimated cost of operating local lines; 2) in chapter VIII, the disastrous consequences which resulted from the war of 1914-1918 for many of the secondary railways, by reason of the increase in the cost of materials and of wages, and by the adoption of the eight-hour day; 3) in the same chapter VIII, fourth part, the new methods to be adopted by the 31 December 1925, when the provisional regime brought into force under stress of circumstances by the act of 22 October 1919, shall have terminated.

The book, which has been very carefully edited, consists of 16 chapters :

In the first, the author, after having defined what is to be legally understood by the terms : *local railways and tramways*, lays down the essential principles of the successive acts of 1865, 1880 and 1913 by which these have been controlled. He cites the advantages and disadvantages and results of the first two of these acts; the act of 1913 was followed too quickly by the war for any opinion to be expressed as to its effects. The chapter is terminated by various tables giving the principal statistics (mileage, gross receipts, net receipts, first cost, etc.) for the local railways at the time when war broke out.

Chapter II gives a short analysis of the laws in force as regards local railways (branch lines, local railways, light railways, etc.) in countries other than France. In chapters III and IV, the author recapitulates and summarises very clearly the reports already mentioned of Messrs. Considère, Colson, Picard, Dupuit, etc., dealing both with the role of feeders to the main lines, which is fulfilled by the local lines, with methods of estimating the utility of the latter from the point of view of the main lines, the local population and the State itself, and also as regards the estimated cost of working such lines. The monthly Bulletins of the Railway Congress Association and the reports of the discussions at the various sessions have been mentioned and discussed in detail in these various articles.

The two chapters which follow (V and VI) comment on the act of 1913, and also on the latter acts and regulations, specifications, concessions, and financial clauses dealing with the construc-

tion and operation, and clauses dealing with re-purchase or forfeiture, etc. Chapter VII draws up a comparison between operation by departments or communes and operation by private concessionnaires, which comparison is also dealt with in the first part of chapter IV.

Chapter VIII deals, as is mentioned above, with an examination of the situation created on the French local railways by the economic crisis caused by the war, and discusses the new regulations which are to be brought into force after 1925.

In the following chapters (IX to XV), the author, returning to general administrative and judicial questions coming within the scope of this book, lays down the principles which govern, from a legal point of view, the construction, maintenance, operation, policing, administrative and financial control of light railways and tramways.

Chapter XVI deals specially with public motor bus services which have developed considerably in France by reason mainly of the subsidies which have been granted to them by local public authorities and by the State itself.

The work is completed by 189 pages of very full information giving the text of the acts, regulations, specifications, form of agreements, etc., dealing with local railways and public bus services.

E. B.

# MONTHLY BIBLIOGRAPHY OF RAILWAYS (1)

*PUBLISHED UNDER THE SUPERVISION OF*

**P. GHILAIN,**

**General secretary of the Permanent Commission of the International Railway Congress Association.**

[ 016 .385. (02 ]

## I. — BOOKS.

### In French.

1925 621 .91. (02

**AMBERT (A.),** ingénieur des arts et manufactures.

**Guide du fraiseur.** Traité théorique et pratique sur les fraises, les machines à fraiser et à tailler, les travaux de fraisage et de taillage. Applications pratiques.

Paris (VI^e^), 15, rue des Saints-Pères; Liége, rue des Dominicains, 8, Librairie polytechnique Ch. Béranger. In-16 (160 × 230) de 248 pages avec 276 fig. (Prix net : 25 francs.)

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1925 621 .86 (02

**ANDREE (W. Ludwig).**

**Statique des appareils de levage et considérations sur la construction analogue des transporteurs, ponts et charpentes.**

Paris (VI^e^), rue des Saints-Pères, 15; Liége, rue des Dominicains, 8, Librairie polytechnique Ch. Béranger. 395 pages, 554 fig. et 1 planche. (Prix : 45 francs.)

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1925 385. (02 (.44)

**Annuaire des chemins de fer et des tramways** (ancien Marchal), 1925, 36^e^ année. (Edition des réseaux français).

Paris (VIII^e^), 33, boulevard Malesherbes. 1 vol. in-8°, 1012 pages, fig. & cartes.

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1920 624. (02

**ARAGON (Ernest),** ingénieur des arts et manufactures, ingénieur d'études de ponts, constructions métalliques et travaux publics.

**Résistance des matériaux appliquée aux constructions.** Méthodes pratiques par le calcul et la statique graphique. Tome 2 : Poutres à travées solidaires. Dénivellation des appuis et lançage des ponts-arcs à paroi pleine et à treillis. Ponts suspendus. Piles métalliques. Assemblages des pièces et appareils d'appui.

Tours, impr. Deslis père, R. et P. Deslis; Paris, Dunod, éditeur, 92, rue Bonaparte. Nouveau tirage. In-8°, 752 pages avec fig. (Prix net : 30 francs.)

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1925 725. (02

**AUCAMUS (E.),** ingénieur des arts et manufactures.

**Bâtiment.** Revisé par **Ph. Rousseau,** secrétaire général de la Société française des ingénieurs coloniaux. A l'usage des ingénieurs, architectes, entrepreneurs, conducteurs, agents voyers, métreurs et commis de travaux.

Tours, impr. Deslis père, R. et P. Deslis; Paris, Dunod, 92, rue Bonaparte. 44^e^ édition, in-16, XXIV-582 pages. (Prix: 10 francs.)

1925 69 (02

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1925 621 .33 (02

**BACHELLERY (André),** ingénieur au corps des mines, ingénieur en chef du matériel et de la traction à la Compagnie des chemins de fer du Midi.

**Chemins de fer électriques.**

Paris (VI^e^), Librairie J.-B. Baillière & fils, 19, rue Hautefeuille. In-8°, 445 pages avec 224 fig. (Prix : 55 francs.)

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1925 621 .8 (02

**BETHMANN (H.).,** ingénieur, professeur de construction de machines à l'Ecole technique d'Altenbourg.

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**Manuel des chemins de fer.** Traction, matériel, exploitation, législation.

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Wintherthur (Suisse), édité par la Société suisse pour la construction de locomotives et de machines. (165 × 245), de 49 pages, 13 fig. et 4 planches.

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**CHEMINS DE FER FRANÇAIS.** Grands réseaux. Matériel et traction. **Spécifications techniques et cahiers des charges unifiés.**

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(1) The numbers placed over the title of each book are those of the decimal classification proposed by the Railway Congress conjointly with the Office Bibliographique International, of Brussels. (See « Bibliographical Decimal Classification as applied to Railway Science », by L. WEISSENBRUCH in the number for November, 1897, of the *Bulletin of the International Railway Congress*, p. 1509.)

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**Etudes expérimentales de technologie industrielle. 58e mémoire. Causes d'usure prématurée des rails.**

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Paris (XVIIIe), Ch. Frémont, 25, rue du Simplon. In-4° (220 × 270), 74 pages & fig.

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1925 625 .611. (02

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**Carte des chemins de fer européens avec un volume donnant les distances des transits de l'Europe.**

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Deutscher Ausschuss für Eisenbeton, Heft 53. **Versuche mit Plattenbalken zur Ermittlung der Einflüsse von wiederholter Belastung, Witterung und Rauchgasen, und zwar auf lange Dauer und bei häufiger Wiederholung** (Erster Teil).

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**MAURER (Edward R.)**, professor, & **ROARK (Ray mond J.)**, assistant professor of mechanics, Univer sity of Wisconsin.

**Technical mechanics :** Statics, kinematics, kinetic

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Firenze, Stabilimento tipografico Pisa e Lampronti. Gr. in-4°, parte I : 493 pagine; parte II : 47 pagine.

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SABOURET (V.). — **Clavage d'une grande voûte** par joints provisoires de sable. (2 500 mots & fig.)

1925 721 .4

Ann. des ponts et chauss., part. techn., mai-juin, p. 263.

LEGAY. — **Sur le calcul des arcs encastrés dans un troisième cas (Note additionnelle).** (2 400 mots et 4 tableaux.)

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Ann. des ponts et chauss., part. techn., juillet-août, p. 5.

JACQUART (J.). — **L'usure et la corrosion** dans les ouvrages métalliques. (20 000 mots, 1 tableau & fig.)

1925 51

Ann. des ponts et chauss., part. techn., juill.-août, p. 92.

PIGEAUD. — Note sur la méthode d'approximations successives de M. E. Picard pour **l'intégration des équations différentielles.** (3 900 mots & fig.)

## Bulletin annoté des Chemins de fer. (Paris.)

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Voies ferrées d'intérêt local. — **Régime des voies ferrées d'intérêt local** après le 31 décembre 1925. — Projet de loi. (4 600 mots.)

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Bull. de la Société d'enc. pr l'ind. nat., avril, p. 345.

PATOUREAU (J.). — La **suspension des véhicules** au moyen de ressorts à air. (2 300 mots & fig.)

## Bulletin de la Société des ingénieurs civils de France. (Paris.)

1925 691 (.73)

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CANDLOT (Ch.). — Le **ciment** aux Etats-Unis. (5 000 mots.)

1925 656 .211.7 (.42 + .493)

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RAVIER (L.). — Sur les **bacs porte-trains** et spécialement sur le service entre l'Angleterre et la Belgique. (3 900 mots & fig.)

## Bulletin technique de la Suisse romande. (Vevey.)

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JAMBÉ (C.). — Reconstruction du **viaduc** de la Paudèze. (2 000 mots & fig.)

1925 691

Bull. techn. de la Suisse romande, n° 22, 24 oct., p. 274.

BOLOMEY (J.). — Futures normes suisses pour les **liants hydrauliques.** (1 000 mots.)

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1925 385 .4

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**Réorganisation des chemins de fer de l'Etat polonais.** (1 800 mots.)

## Bulletin de l'Union internationale des chemins de fer (Paris).

1924 656 .223.2

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Règlement international concernant les **wagons de particuliers.** (2 000 mots & fig.)

1925 625 .253 (

Bull. de l'Union intern. des ch. de fer, mars, p. 1.

WEISS (M.). — Rapport présenté par les Chem de fer fédéraux suisses à la Commission des « qu tions techniques » de l'U. I. C. (Session avril-mai 19 à Florence) sur la question d'emploi et de fonction ment du **frein continu** dans les trains de marchandis (13 700 mots & 2 tableaux.)

1925 656 .254 (.4

Bull. de l'Union intern. des ch. de fer, mars, p. 29.

ROGINSKY (N. O.). — Le « **Dispatching system** sur les chemins de fer russes. (3 400 mots & fig.)

1925 385. (09.1 (.49

Bull. de l'Union intern. des ch. de fer, avril, p. 7.

Les **Chemins de fer fédéraux suisses** en 1923 et 19 (4 300 mots, 4 tableaux & fig.)

1925 385

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Les **Chemins de fer de la République tchécoslovaq** (2 300 mots, 4 tableaux & fig.)

1925 385. (.09.1 (.4

Bull. de l'Union intern. des ch. de fer, juillet, p. 20.

Les **Chemins de fer fédéraux autrichiens.** (6 900 mo 5 tableaux & fig.)

1925 385 .4 (.43

Bull. de l'Union intern. des ch. de fer, sept., p. 11.

**Réorganisation administrative et technique** du rése de la Compagnie des chemins de fer du Sud. (4 4 mots & fig.)

1925 385 .113 (.49

Bull. de l'Union intern. des ch. de fer, sept., p. 18.

Les **Chemins de fer néerlandais** en 1923 et 19 (3 700 mots & 3 tableaux.)

1925 385 .113 (.4

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Les **chemins de fer italiens de l'Etat** pendant l'exe cice 1923-1924. (2 600 mots & 7 tableaux.)

## Génie civil. (Paris.)

1925 624. (

Génie civil, n° 2220, 28 février, p. 207.

CONTY (H. A. de). — **L'entretien des ponts méta liques** franchissant des voies ferrées à grande fréque tation. (5 600 mots & fig.)

1925 625 .6

Génie civil, n° 2222, 14 mars, p. 259.

PETIT (L.). — L'utilisation des **trucks-transporteu** sur les chemins de fer à voie étroite. (3 800 mots & fi

1925 624 .51 (.7

Génie civil, n° 2223, 21 mars, p. 277.

Le **pont suspendu** de 497 mètres de portée de Be Mountain, sur l'Hudson (New York). (2 000 mots & fi

1925 62. (01 & 691. (

Génie civil, n° 2223, 21 mars, p. 281.

**Calcul rapide des pièces en béton armé** à compressi et flexion composées. (1 100 mots, 2 tableaux & fi

**1925** **625 .235**

Génie civil, n° 2224, 28 mars, p. 315.

**Nouvelle serrure,** système Birlé, pour la fermeture des portières des voitures des chemins de fer. (550 mots & fig.)

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**1925** **621 .132.8**

Génie civil, n° 2225, 4 avril, p. 325.

L'état actuel de la traction sur voies ferrées par **moteurs à combustion interne.** (3 300 mots & fig.)

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**1925** **621 .335 (.73)**

Génie civil, n° 2227, 18 avril, p. 373.

Les **locomotives électriques** en Amérique. (4 000 mots & fig.)

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**1925** **621 .133.7 (.44)**

Génie civil, n° 2227, 18 avril, p. 384.

Le **réchauffage de l'eau d'alimentation** des chaudières de locomotives. Essais effectués sur le réseau P. L. M. (3 500 mots & fig.)

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**1925** **725 .36 (.44)**

Génie civil, n° 2229, 2 mai, p. 421.

CAUFOURIER (P.). — Le **silo à grains** du port de Dunkerque. (2 300 mots, 1 tableau & fig.)

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**1925** **624 (.44 + .42)**

Génie civil, n° 2230, 9 mai, p. 457.

JAEGER (J.). — Projet de traversée du Pas-de-Calais au moyen d'une **double jetée formant chenal et de viaducs pour routes et voies ferrées.** (6 500 mots & fig.)

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**1925** **621 .331 (.494)**

Génie civil, n° 2231, 16 mai, p. 473.

GIUDICI (C. A.) & WUNENBURGER (G.). — **L'électrification des chemins de fer suisses.** (3 200 mots & fig.)

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**1925** **62. (01 & 721 .9**

Génie civil, n° 2231, 16 mai, p. 479.

DECOUFLÉ. — La **résistance des joints** en construction métallique. (3 900 mots & fig.)

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**1925** **62. (01 & 624 .2**

Génie civil, n° 2233, 30 mai, p. 531.

CHAUDY (F.). — Calcul des hourdis des **tabliers d'ouvrages d'art en béton armé.** (1 800 mots & fig.)

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**1925** **62. (01 & 669 .1**

Génie civil, n° 2237, 27 juin, p. 626.

GUILLET (L.). — **Limite d'élasticité et module d'élasticité** dans les produits métallurgiques. (1 800 mots et 1 tableau.)

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**1925** **621 .335 (.494) & 621 .338 (.494)**

Génie civil, n° 2237, 27 juin, p. 637.

**Automotrices électriques** à courant monophasé du Chemin de fer des Alpes bernoises. (300 mots & fig.)

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**1925** **624 .52 (.44)**

Génie civil, n° 2238, 4 juillet, p. 1.

LEINEKUGEL LE COCQ (G.). — **Pont cantilever suspendu rigide,** sur le Trieux, à Lézardrieux (Côtes-du-Nord). (5 200 mots & fig.)

## La Science et la Vie. (Paris.)

**1925** **625 .4 (.44)**

La Science et la Vie, janvier, p. 29.

MEYAN (P). — **L'aéro-tram** projeté de la Porte de La Chapelle à Saint-Denis. (1 600 mots & fig.)

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**1925** **621 .132.1 (.44) & 621 .138.4 (.44)**

La Science et la Vie, juin, p. 457.

RICHON (A.). — Cent années de chemins de fer. **Locomotives et mécaniciens.** (13 000 mots & fig.)

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**1925** **656 .28 (01**

La Science et la Vie, août, p. 99.

MARCHAND (J). — Les mesures et manœuvres de secours prises et effectuées d'urgence après un **accident de chemin de fer.** (2 500 mots & fig.)

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**1925** **656 .257 (.44)**

La Science et la Vie, septembre, p. 193.

BROCARD (R.). — **De la façon dont, à distance, aiguilles et signaux sont manœuvrés,** dépend la sécurité sur les voies ferrées. (1 600 mots & fig.)

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## Les chemins de fer et les tramways. (Paris.)

**1925** **625 .611**

Les ch. de fer et les tramw., août, p. 120.

ROY (R.). — Recherche des principes applicables au calcul de la **rémunération du concessionnaire ou du fermier dans le cas où le régime d'exploitation est la régie intéressée.** (6 600 mots, 5 tableaux & fig.)

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**1925** **656 .259**

Les ch. de fer et les tramw., septembre, p. 142.

**Signalisation automatique sur locomotives en marche** et sur voie ferrée. (1 100 mots & fig.)

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**1925** **656 .251**

Les ch. de fer et les tramw., septembre, p. 145.

Perfectionnements aux **signaux lumineux** protecteurs de voie unique. (1 500 mots & fig.)

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**1925** **621 .336**

Les ch. de fer et les tramw., septembre, p. 147.

**Frotteur de prise de courant** pour traction électrique. (1 000 mots & fig.)

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**1925** **625 .212**

Les ch. de fer et les tramw., septembre, p. 150.

Procédé pour la **remise en état des roues** à boudin usagées. (900 mots & fig.)

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**1925** **621 .31**

Les ch. de fer et les tramw., septembre, p. 152.

Sur le **déclenchement des disjoncteurs** haute tension. (900 mots & fig.)

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**1925** **625 .23 (.44)**

Les ch. de fer et les tramw., octobre, p. 156.

Exposition internationale des arts décoratifs et industriels modernes. **Section des transports.** (2 600 mots & fig.)

1925 62. (01 & 692

Les ch. de fer et les tramw., octobre, p. 162.

DESGARDES (E.). — Remarques concernant les essais prévus par les spécifications techniques unifiées nos 8 et 11 pour les **aciers destinés à la fabrication des ressorts** des 11 avril et 14 novembre 1918. (2 200 mots, 8 tableaux & fig.)

1925 621 .132.8

Les ch. de fer et les tramw., octobre, p. 167.

**Locomotive à deux foyers** et deux tenders directeurs. (3 700 mots & fig.)

## L'Industrie des voies ferrées et des transports automobiles. (Paris.)

1925 621 .338

L'Ind. voies ferrées et transp. autom., janvier, p. 28.

HARMEL (C.). — Perfectionnements apportés aux **voitures motrices** au point de vue des dépenses de premier établissement, d'entretien et de consommation. Essieux rayonnants; roulements à billes et à rouleaux. (7 700 mots & fig.)

1925 625 .614

L'Ind. voies ferrées et transp. autom., février, p. 108.

D'HOOP (E.). — Perfectionnements apportés aux **voies et appareils de voies** : construction, commandes électriques et mécaniques des aiguillages. (8 000 mots & fig.)

1925 625 .614

L'Ind. voies ferrées et transp. autom., mars, p. 157.

LO BALBO (P.). — Perfectionnements apportés aux **appareils de voies**. (8 000 mots, tableaux & fig.)

1925 621 .333

L'Ind. voies ferrées et transp. autom., avril, p. 210.

Conditions de réception des **moteurs électriques de traction** à courant continu pour voies ferrées d'intérêt local. (3 800 mots, 2 tableaux & fig.)

1925 625 .15

L'Ind. voies ferrées et transp. autom., avril, p. 216.

TORRES Y ESTRADA (J.). — Perfectionnements apportés aux **voies et appareils de voies**. (9 500 mots.)

1925 625 .2 (01

L'Ind. voies ferrées et transp. autom., juin, p. 283.

RÉSAL (E.). — Au sujet de la **stabilité et du confortable du matériel de chemins de fer** (2 900 mots & fig.)

1925 625 .112

L'Ind. voies ferrées et transp. autom., juillet, p. 319.

**La voie étroite (et particulièrement la voie de 1 mètre d'écartement)**. Avantages et limites actuelles de son rendement. (5 400 mots, 3 tableaux & fig.)

1925 621 .132.8 (.45) & 621 .335 (.45)

L'Ind. voies ferrées et transp. autom., juillet, p. 338.

Résumé de la note : « **Les locomotives pétroléo et Diesel-électriques** en construction en Italie. (2 300 mots & fig.)

1925 621 .333

L'Ind. voies ferrées et transp. autom., août, p. 371.

Corrections proposées aux règles générales d'unification pour la **réception des moteurs de traction à courant continu** pour voies ferrées d'intérêt local et dispositions complémentaires recommandées pour les moteurs de traction à courant continu. (voie normale). (2 500 mots, 2 tableaux & fig.)

1925 385. (09.1 (.42)

L'Ind. voies ferrées et transp. autom., sept., p. 414.

Le réseau du **Chemin de fer de l'Est de Lyon**. (6 800 mots, 3 tableaux & fig.)

## Revue générale des chemins de fer. (Paris.)

1925 385 .4 (.42)

Revue générale des ch. de fer, février, p. 100.

PESCHAUD (M.). — Le **groupement des Compagnies de chemins de fer** en Grande-Bretagne. (7 400 mots & 2 tableaux.)

1925 621 .133.7 (.44)

Revue générale des ch. de fer, février, p. 114.

PARMANTIER (A.). — Le **réchauffage de l'eau d'alimentation** des chaudières-locomotives sur le réseau P.-L.-M. (4 400 mots, 1 tableau & fig.)

1925 385 .113 (.44)

Revue générale des ch. de fer, février, p. 127.

**Résultats obtenus en 1923** sur le réseau des chemins de fer de l'Etat en France d'après les comptes d'administration publiés pour ladite année. (10 tableaux.)

1925 656 .212.6

Revue générale des ch. de fer, février, p. 162.

Effet produit par les **culbuteurs sur les organes des wagons**. (1 300 mots & fig.)

1925 621 .132.8 (.43)

Revue générale des ch. de fer, février, p. 165.

La première **locomotive « Krupp » à turbines**. (2 600 mots & fig.)

1925 656 .253

Revue générale des ch. de fer, mars, p. 185.

MARTY & PICARD. — Note sur les **appareils de répétition des signaux sur les locomotives** employés par la Compagnie de l'Est. (5 000 mots & fig.)

1925 385 .113 (.44)

Revue générale des ch. de fer, mars, p. 199.

Les **résultats d'exploitation** du réseau des chemins de fer de l'Etat en 1923. (3 400 mots & 2 tableaux.)

1925 621 .135.2
vue générale des ch. de fer, mars, p. 243.
**Réparation des bandages** par soudure électrique. 200 mots & fig.)

1925 625 .122 (.44)
vue générale des ch. de fer, avril, p. 153.
JULLIEN. — Note sur les procédés de **consolidation** s **plate-formes argileuses.** (2 000 mots & fig.)

1925 625 .123 (.44)
vue générale des ch. de fer, avril, p. 158.
SABOURET. — Etude expérimentale de l'**ascension** **l'argile à travers le ballast.** (1 400 mots, 1 tableau fig.)

1925 621 .7 (.44)
vue générale des ch. de fer, avril, p. 164.
BLOCH (M.). — Note sur l'**organisation du travail** **ns les grands ateliers de locomotives** de la Compa- ie du chemin de fer de Paris à Orléans. (13 000 mots, bleaux & fig.)

1925 529 .75 (.43)
vue générale des ch. de fer, avril, p. 220.
**La transmission de l'heure** sur les chemins de fer lemands. (750 mots & fig.)

1925 621 .133.7 (.44)
vue générale des ch. de fer, mai, p. 363.
VIGNAL (H.). — L'**épuration chimique de l'eau** sur réseau de la Compagnie Paris-Lyon-Méditerranée. 400 mots & fig.)

1925 621 .134.1 (.44)
evue générale des ch. de fer, mai, p. 414.
**Tenders moteurs** à turbine. (1 700 mots.)

1925 621 .133.7 (.42)
evue générale des ch. de fer, juin, p. 433.
BOULIÈRE. — Le **réchauffage de l'eau d'alimenta-** **on des chaudières de locomotives** sur le réseau 'Alsace et de Lorraine. (8 600 mots, tableaux & fig.)

1925 385. (09.1 (.47)
evue générale des ch. de fer, juin, p. 446.
**La Pologne et ses communications européennes.** 15 300 mots, tableaux & fig.)

1925 385. (09.1 (.495)
Revue générale des ch. de fer, juin, p. 470.
**Les chemins de fer de l'Etat hellénique** durant exercice 1923-1924. (2 600 mots & fig.)

1925 621 .133.5 (.44)
Revue générale des ch. de fer, juillet, p. 3.
JAPIOT (M.). — **L'échappement à trèfle des loco-** **notives** de la Compagnie Paris-Lyon-Méditerranée. 5 000 mots & fig.)

1925 385. (09.1 (.47)
Revue générale des ch. de fer, juillet, p. 13.
**Les chemins de fer russes** à la fin de 1924. (12 500 mots & 8 tableaux.)

1925 385 .113 (.44)
Revue générale des ch. de fer, juillet, p. 42.
**Les résultats de l'exploitation** des cinq grandes compagnies de chemins de fer en 1924. (11 300 mots.)

1925 621 .33 (.73)
Revue générale des ch. de fer, juillet, p. 76.
Résultats de l'**électrification** du Chicago Milwaukee and St. Paul RR. (1 700 mots & 4 tableaux.)

## Revue politique et parlementaire. (Paris.)

1925 385 .15 (.44)
Revue politique et parlementaire, 10 mars, p. 428.
ALLIX (G.). — Le gouvernement et les compagnies de chemins de fer. (4 600 mots.)

1925 385 .113 (.44)
Revue politique et parlementaire, 10 mai, p. 275.
ALLIX (G.). — **Les grands réseaux français** en 1924. (4 200 mots.)

1925 385 .113 (.43)
Revue politique et parlementaire, 10 août, p. 300.
ALLIX (G.). — **Les chemins de fer allemands.** (2 700 mots.)

1925 385. (09.3 (.71)
Revue politique et parlementaire, 10 septembre, p. 350.
GUY (C.). — Le « **Canadian Pacific Railway** ». (7 700 mots.)

1925 385 .1 (.44)
Revue politique et parlementaire, 10 octobre, p. 41.
LORIN (H.). — Où en sont nos **grands réseaux de chemins de fer.** (8 500 mots.)

## Revue universelle des mines, de la métallurgie, des travaux publics, des sciences et des arts appliqués à l'industrie. (Liége.)

1925 62. (01
Revue universelle des mines, n° 1, 1er avril, p. 6.
CENTNER (P.). — **Méthode de détermination des efforts secondaires** dus à la déformation dans les systèmes à joints rigides. (7 000 mots, 1 tableau & fig.)

1925 621 .116
Revue universelle des mines, n° 5, 1er juin, p. 246.
HENRY (R. A.). — La théorie du **lavage du charbon** par voie humide. (8 600 mots, 1 tableau & fig.)

## Revue universelle des transports. (Paris.)

1925 621 .132.6 (.44)
Revue universelle des transports, n° 24, 15 février, p. 49.
PAHIN (L.-A.-H.). — Les locomotives à vapeur, type « Mikado ». **Locomotives-tenders** récentes, avec et sans condensation, du chemin de fer de Paris à Orléans. (3 800 mots & fig.)

1925 625 .123
Revue universelle des transports, n° 24, 15 février, p. 55.
BOUVET. — **Déglaisements et assainissements des voies ferrées.** (3 800 mots & fig.)

**1925** **625 .143.3**
Revue universelle des transports, n° 27, 1er avril, p. 97.
Note complémentaire sur l'**usure ondulatoire des rails.** (2 600 mots & fig.)

**1925** **621 .132.5 (.44)**
Revue universelle des transports, n° 27, 1er avril, p. 101.
PAHIN (L.). — Les locomotives à vapeur, **type « Mountain ».** (3 000 mots & fig.)

**1925** **621 .33 (.44)**
Revue universelle des transports, n° 29, 1er mai, p. 129.
TCHERNIACK-JOANID (D.). — L'**électrification** des lignes de banlieue des chemins de fer de l'Etat. (2 200 mots & fig.)

**1925** **656 .222.4 (.44)**
Revue universelle des transports, n° 30, 15 mai, p. 147.
Les **services rapides et express** des chemins de fer de Paris à Lyon et à la Méditerranée. (1 500 mots, 2 tableaux & fig.)

**1925** **621 .135.2 & 625 .214**
Revue universelle des transports, n° 31, 1er juin, p. 161.
Les applications des **roulements à billes,** à galets et à rouleaux élastiques au matériel roulant. (2 400 mots & fig.)

**1925** **385. (07.1 (.44)**
Revue universelle des transports, n° 31, 1er juin, p. 173.
MERCIER (E.). — L'organisation de l'**apprentissage** dans une grande entreprise de transports en commun. (1 400 mots.)

**1925** **621 .133**
Rev. univers. des transp., n° 34, 15 juill.-1er août, p. 205.
ROY (M.). — Etude thermodynamique de quelques perfectionnements possibles de la **locomotive à vapeur.** (2 900 mots, 5 tableaux & fig.)

**1925** **621 .331 (.44)**
Revue universelle des transports, n° 35, 15 août, p. 228.
JOANID-TCHERNIACK (D.). — L'**électrification** des lignes de banlieue des Chemins de fer de l'Etat. Les sous-stations. (1 400 mots & fig.)

**1925** **625 .143.5 (.44)**
Revue universelle des transports, n° 36, 1er sept., p. 248.
Le **système de voie ferrée mécanique** Sautreau. (800 mots & fig.)

## In German.

### Archiv für Eisenbahnwesen. (Berlin.)

**1925** **385 .15 (.54)**
Archiv für Eisenbahnwesen, März-April, S. 247.
VOIGT (G.). — **Staat und Eisenbahnwesen** in British-Indien. (13 200 Wörter.)

**1925** **385 .517 (.43)**
Archiv für Eisenbahnwesen, März-April, S. 345.
KUHATSCHECK (O.). — **Die Arbeiterpensionskassen, die Krankenkassen und die Unfallversicherung** bei der Deutschen Reichsbahn im Jahr 1924. (7 200 Wörter & 3 Tabellen.)

**1925** **313 .385 (.**
Archiv für Eisenbahnwesen, März-April, S. 376.
BALTZER (F.). — Die **chinesischen Eisenbahnen** Kalenderjahr 1922. (2 000 Wörter & Tabellen.)

**1925** **313 .385 (.4**
Archiv für Eisenbahnwesen, März-April, S. 390.
Die **Eisenbahnen der Schweiz** im Jahr 1922. (Tab len.)

**1925** **385 .113 (.**
Archiv für Eisenbahnwesen, März-April, S. 399.
Die **Betriebsergebnisse** der fünf grossen französisch Eisenbahngesellschaften in den Jahren 1921 und 19 (Tabellen.)

**1925** **313 .385 (.4**
Archiv für Eisenbahnwesen, März-April, S. 409.
Die **Eisenbahnen in Norwegen** in den Jahren 1921 und 1922-23. (Tabellen.)

**1925** **313 .385 (.**
Archiv für Eisenbahnwesen, Mai-Juni, S. 505.
Die **Eisenbahnen des Deutschen Reichs.** 1921 1922. (Tabellen.)

**1925** **385. (09.1 (.**
Archiv für Eisenbahnwesen, Mai-Juni, S. 526.
OVERMANN, Dr. — Die **Eisenbahnen in Niederländisch-Ostindien.** (5 000 Wörter.)

**1925** **313 .385 (.4**
Archiv für Eisenbahnwesen, Mai-Juni, S. 541.
ROESNER (E.). — Die **Eisenbahnen in Spanien** den Jahren 1912 bis 1916 und 1918 bis 1922. (1 Wörter & Tabellen.)

**1925** **313 .385 (.**
Archiv für Eisenbahnwesen, Mai-Juni, S. 584.
Die **Japanischen Eisenbahnen** im Rechnungsj 1920-21 und die durch das Erdbeben verursach Schäden. (3 000 Wörter & Tabellen.)

**1925** **385 .4 (.4**
Archiv für Eisenbahnwesen, Juli-August, S. 718.
FRICKE. — Die neue **Eisenbahnordnung in Spani** (3 000 Wörter.)

**1925** **313 .385 (.4**
Archiv für Eisenbahnwesen, Juli-August, S. 727.
ROESNER (E.). — Die **Eisenbahnen Österreichs** den Jahren 1922 und 1923. (400 Wörter & Tabellen.

### Glasers Annalen. (Berlin.)

**1925** **656 .28**
Glasers Annalen, Heft 1, 1. Januar, S. 3.
GÜNTHER (K.). — **Eisenbahnunfälle.** (5 000 W ter, Tabellen & Abb.)

**1925** **621 .133.1 & 625 .245**

Glasers Annalen, Heft 1, 1. Januar, S. 14.

LANDSBERG. — **Messwagen für Wärmewirtschaft** bei der Deutschen Reichsbahn Gesellschaft. (2 500 Wörter & Abb.)

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**1925** **621 .392 & 625 .143.4**

Glasers Annalen, Heft 1, 1. Januar, S. 18.

**Elektrischen Schienenschweissen** nach dem Stumpf-Schweiss-Verfahren System Jacobs, der Lorrain Steel Co., Johnstown Pa. (2 000 Wörter & Abb.)

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**1925** **621 .138.1 (.43)**

Glasers Annalen, Heft 6, 15. März, S. 129.

KOBLENZ (H.). — Neuzeitliche **Lokomotiv-Bekohlungsanlagen.** (2 600 Wörter & Abb.)

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**1925** **385. (07.2 (.43) & 625 .251 (.43)**

Glasers Annalen, Heft 7, 1. April, S. 137.

METZKOW. — Messeinrichtungen für **Bremsversuche.** (7 500 Wörter & Abb.)

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**1925** **621 .335 (.43)**

Glasers Annalen, Heft 7, 1. April, S. 153.

**Sechsachsiger Wechselstrom-Doppeltriebwagen** 2./3. Klasse für die Hamburger Stadt- und Vorortbahnen. (1 100 Wörter & Abb.)

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**1925** **669 .1**

Glasers Annalen, Heft 12, 15. Juni, S. 259.

KÜHNEL. — **Das Einsatzhärten** und seine Anwendung in der Eisenbahnfahrzeugindustrie. (2 300 Wörter & Abb.)

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**1925** **625 .26**

Glasers Annalen, Heft 12, 15. Juni, S. 265.

LORENZ (K.). — Ueber die **Unterhaltung der Güterwagen.** (6 000 Wörter.)

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**1925** **625 .245 (.43)**

Glasers Annalen, Heft 12, 15. Juni, S. 271.

JAEGER (F. K.). — **Unterrichtswagen.** (1 700 Wörter & Abb.)

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**1925** **621 133.3**

Glasers Annalen, Heft 1, 1. Juli, S. 13.

NORDLING (K. E.) & BENGTZON (R.). — Beiträge zur Kenntnis der Widerstände in dem **Rohrsysteme des Lokomotivkessels** mit vergleichenden Untersuchungen über Widerstände und Wärmeübertragung. (3 000 Wörter & Abb.)

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**1925** **621 .138.5 (.43) & 625 .26 (.43)**

Glasers Annalen, Heft 2, 15. Juli, S. 21.

KÜHNE. — **Neuordnung des Werkstättenwesens** der Deutschen Reichsbahn-Gesellschaft. (10 300 Wörter.)

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## In English.

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### American Railway Association. (Signal Section.) (New York.)

**1925** **625 .253 (.73) & 656 .253 (.73)**

Amer. Ry. Ass$^{on}$, Signal Section, No. 5, April, p. 659.

WOOD (G. H.). — The relation of the **air brake** to **train control.** (7 600 words.)

**1925** **656 .257 (.73)**

Amer. Ry. Ass$^{on}$, Signal Section, No. 1, August, p. 38.

Committee II. — **Mechanical Interlocking.** (11 000 words.)

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**1925** **656 .256.3 (.73)**

Amer. Ry. Ass$^{on}$, Signal Section, No. 1, August, p. 116.

Committee IV. — Direct current **automatic block signaling.** (3 400 words & fig.)

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**1925** **656 .25 (.73)**

Amer. Ry. Ass$^{on}$, Signal Section, No. 1, August, p. 129.

Committee I. — **Economics of railway signaling.** (5 000 words & fig.)

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### Bulletin, American Railway Engineering Association. (Chicago.)

**1925** **692 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, January, p. 489.

Report of Committee XX. — **Uniform general contract forms.** (13 000 words.)

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**1925** **624 .2 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, January, p. 515.

Report of Committee VII. — **Wooden bridges and trestles.** (15 600 words, tables & fig.)

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**1925** **625 .14 (.73) & 625 .15 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, January, p. 553.

Report of Committee V. — **Track.** (10 000 words & fig.)

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**1925** **625 .162 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, January, p. 575.

Report of Committee IX. — Signs, fences and crossings. (15 000 words & fig.)

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**1925** **625 .143 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, January, p. 613.

Report of Committee IV. — **Rail.** (10 000 words, 5 tables & fig.)

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**1925** **656 .21 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, February, p. 657.

Report of Committee XIV. — **Yards and terminals.** (38 000 words, tables & fig.)

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**1925** **625 .18 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, February, p. 773.

Report of Committee XI. — **Records and accounts.** (26 000 words & fig.)

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**1925** **656 .22 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, February, p. 859.

Report of Committee XXI. — **Economics of railway operation.** (25 000 words, tables & fig.)

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**1925** **625 .1 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, March, p. 929.

Report of Committee XXII. — **Economics of railway labor.** (18 800 words, tables & fig.)

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**1925** **625 .142.2 (.73)**

Bull. Amer. Ry. Eng. Ass$^{on}$, March, p. 1009.

Report of Committee III. — **Ties.** (16 000 words, tables & fig.)

**1925** **625 .14 (01 (.73)**
Bull. Amer. Ry. Eng. Ass^on^, March, p. 1081.
Fourth progress report. Special Committee on **stresses in railroad track.** (38 000 words, tables & fig.)

**1925** **625 .143.2 (.73)**
Bull. Amer. Ry. Eng. Ass^on^, July, p. 12.
Standard specifications for **open-hearth carbon steel rails-1924.** (1 900 words & 1 table.)

**1925** **725 .3 (.73)**
Bull. Amer. Ry. Eng. Ass^on^, July, p. 19.
Floors for **railway buildings.** (11 000 words & fig.)

## Electric Railway Journal. (New York.)

**1925** **625 .143.4 (.73)**
Electric Railway Journal, No. 3, January 17, p. 87.
**Bond testing** and maintenance practice. (3 000 words, 1 table & fig.)

**1925** **625 .13 (.73)**
Electric Railway Journal, No. 5, January 31, p. 179.
**Sub-surface terminal** for Los Angeles. (1 200 words & fig.)

**1925** **621 .335 (.73)**
Electric Railway Journal, No. 5, January 31, p. 187.
I. T. S. builds **articulated locomotives.** (1 500 words & fig.)

**1925** **621 .338 (.73)**
Electric Railway Journal, No. 6, February 7, p. 211.
**I. C. R. R. cars for Chicago electrification** designed for heavy service. (2 700 words & fig.)

**1925** **625 .13 (.73)**
Electric Railway Journal, No. 11, March 14, p. 409.
**Subway** proposed in Pittsburgh. (2 600 words & fig.)

**1925** **625 .14 (.73)**
Electric Railway Journal, No. 16, April 18, p. 615.
GAUTHIER (G. J.). — **Tieless track** laid in Hot Springs, Ark. (1 400 words & fig.)

**1925** **621 .33 (.73)**
Electric Railway Journal, No. 17, April 25, p. 647.
COOKE (B. F.). — **Steam line electrified** to furnish interurban service. (3 800 words & fig.)

**1925** **621 .338 (.73)**
Electric Railway Journal, No. 19, May 9, p. 720.
Many innovations in **Grand Rapids cars.** (2 200 words & fig.)

**1925** **621 .33 (.494)**
Electric Railway Journal, No. 19, May 9, p. 727.
**Electrification of Swiss Federal Railways** progressing rapidly. (1 900 words, 1 table & fig.)

**1925** **388 (.73)**
Electric Railway Journal, No. 24, June 13, p. 917.
**Train operation** by the Interborough. (4 700 words & fig.)

**1925** **388 (.73**
Electric Railway Journal, No. 26, June 27, p. 1009.
GORDON (C.). — Electric railways keep pace i**rapidly growing Texas cities.** (4 000 words & fig.)

**1925** **388 (.73**
Electric Railway Journal, No. 1, July 4, p. 3.
**Electric Rapid Transit** inaugurated on Staten Island (2 400 words & fig.)

## Engineer. (London.)

**1925** **621 .335 (.460**
Engineer, No. 3603, January 16, p. 84.
**Electric locomotives** for the Norte Railway of Spain (1 200 words & fig.)

**1925** **621 .131.1 (.44**
Engineer, No. 3606, February 6, p. 153.
BURTON ALEXANDER (J. T.). — **French locomotives** performances. (4 600 words.)

**1925** **621 .11**
Engineer, No. 3607, February 13, p. 197.
DAHLERUS (J. B.). — **Anti-friction bearing** applications for heavy duty. (4 200 words & fig.)

**1925** **625 .4 (.42 + .44**
Engineer, No. 3609, February 27, p. 245.
A proposed **submarine tubular railway.** (900 word & fig.)

**1925** **621 .138.**
Engineer, No. 3610, March 6, p. 260.
The general organisation of **running sheds.** (5 00 words.)

**1925** **621 .33**
Engineer, No. 3612, March 20, p. 334.
22 000 volt **motor generator locomotives.** (2 200 word & fig.)

**1925** **621 .335 (.45**
Engineer, No. 3613, March 27, p. 358.
An Italian double-ended **Diesel-electric locomotive** (1 250 words & fig.)

**1925** **385. (07.1**
Engineer, No. 3614, April 3, p. 372.
TRIPP (G. W.). — **Apprenticeship** in the roya ordnance factories. (4 200 words.)

**1925** **621 .132.6 (.42**
Engineer, No. 3616, April 17, p. 433.
A geared **shunting locomotive.** (1 800 words & fig.)

**1925** **621 .33 (.42**
Engineer, No. 3618, May 1, p. 486.
New **single-phase equipment** for the Southern Railway. (1 100 words & fig.)

**1925** **621 .62 (.71**
Engineer, No. 3618, May 1, p. 492.
**New bridge** over the Niagara. (1 200 words & fig.)

1925 621 .132.5 (.73)
Engineer, No. 3619, May 8, p. 509.
POULTNEY (E. C.). — Fifty per cent. **cut-off locomotives.** (3 000 words, 1 table & fig.)

1925 621 .132.8 (.931)
Engineer, No. 3621, May 22, p. 570.
**Railway steam car** for new Zealand. (1 300 words & fig.)

1925 621 .134.1
Engineer, No. 3621, May 22, p. 575.
Fifty per cent. **Cut-off locomotives.** (1 000 words.)

1925 621 .132.8 (.43) & 621 .43 (.43)
Engineer, No. 3621, May 22, p. 578.
**Diesel locomotive** design in Germany. (2 000 words & fig.)

1925 621 .335 (.73)
Engineer, No. 3622, May 29, p. 606.
Triple **Electric Locomotive** for the Virginian Railway. (1 700 words & fig.)

1925 621 .87 (.42)
Engineer, No. 3624, June 12, p. 658.
20-ton **Goliath crane.** (1 300 words & fig.)

1925 625 .13 (.42)
Engineer, No. 3626, June 26, p. 701.
Waterloo **temporary bridge.** (2 600 words & fig.)

## Engineering. (London.)

1925 621 .335 (.73)
Engineering, No. 3083, January 30, p. 125.
**2-8-2 electric locomotives** on the Pennsylvania Railroad. (3 300 words & fig.)

1925 625 .13
Engineering, No 3084, February 6, p. 159.
The **repair of La Voulte cast-iron railway viaduct.** (2 400 words & fig.)

1925 621 .114
Engineering, No. 3085, February 13, p. 208.
DAHLERUS (J. B.). — **Anti-friction bearing applications** for heavy duty. (3 500 words, 4 tables & fig.)

1925 625 .13 (.42)
Engineering, No. 3087, February 27, p. 250.
**Bridge reconstruction work** of the Ministry of transport. (3 000 words & fig.)

1925 621 .131.3 (.73)
Engineering, No. 3091, March 27, p. 371.
FRY (L. H.). — Twenty years' work on the **Pennsylvania Railroad locomotive testing plant.** (1 800 words.)

1925 621 .132.5 (.73)
Engineering, No. 3091, March 27, p. 381.
High-pressure compound **2-8-0 type locomotive.** (2 300 words & fig.)

1925 656 .281 (.42)
Engineering, No. 3095, April 24, p. 513.
The Lytham **railway accident.** (1 600 words.)

1925 385. (09.1 (.66)
Engineering, No. 3096, May 1, p. 550.
The **Nigerian Railways.** (2 700 words, 1 table & 1 map.)

1925 669 .1
Engineering, No. 3097, May 8, p. 585.
AITCHISON (L.) & JOHNSON (L. W.). — The effect of grain upon the **fatigue strength of steels.** (1 500 words.)

1925 669 .1
Engineering, No. 3097, May 8, p. 585.
JEVONS (J. D.). — Strain detection in **mild steel** by special etching. (3 300 words & fig.)

1925 669 .1
Engineering, No. 3097, May 8, p. 588.
TURNER (T. H.) & JEVONS (J. D.). — The detection of strain in **mild steels.** (2 000 words & fig.)

1925 669 .1 & 625 .143.2
Engineering, No. 3099, May 22, p. 649.
HULTGREN (A.). — « Flakes » or « hair-cracks » in chromium steel, with a discussion on « **shattered zone** » **and** « **transverse fissures** » **in rails.** (4 000 words & fig.)

1925 669 .1
Engineering, No. 3102, June 12, p. 739.
The physical chemistry of **steel-making processes.** (2 500 words.)

1925 385. (09.3 (.42)
Engineering, No. 3104, June 26, p. 783.
The **railway centenary.** (13 000 words & fig.)

1925 385. (06.119
Engineering, No. 3104, June 26, p. 804.
The **International Railway Congress.** (8 600 words.)

1925 656 .254
Engineering, No. 3104, June 26, p. 814.
GRIFFITHS (R. S.). — The double-wire system of **mechanical signalling.** (3 200 words & fig.)

1925 621 .132.8 (.42)
Engineering, No. 3105, July 3, p. 12.
**Garratt locomotive** for the London and North Eastern Railway. (2 000 words & fig.)

## Engineering News-Record. (New York.)

1925 625 .13 (.73)
Engineering News-Record, No. 4, January 22, p. 144.
Missouri river **bridge rebuilt** for heavier loading (1 100 words.)

1925 62. (01
Engineering News-Record, No. 6, February 5, p. 225.
MOORE (H. F.). — **Fatigue tests of metals** and the theory of elasticity. (2 300 words.)

1925 625 .13 (.73)
Engineering News-Record, No. 7, February 12, p. 264.
**Open cut and tunnel** in Manhattan schist. (2 400 words & fig.)

1925 625 .13 & 691
Engineering News-Record, No. 9, February 26, p. 350.
WEBB (W. F.). — Placing **concrete lining** in the Hetch Hetchy tunnels. (1 800 words & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 10, March 5, p. 401.
**Driving a small tunnel** under air pressure at Seattle. (1 000 words & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 12, March 19, p. 466.
WELTY (H. T.). — Planning and construction of New York Central lines' new **Hudson river bridge.** (6 400 words & fig.)

1925 624 .7 (.73)
Engineering News-Record, No. 13, March 26, p. 516.
Continuous **three-span concrete railway bridge.** (550 words & fig.)

1925 624 .52 (.73)
Engineering News-Record, No. 14, April 2, p. 561.
WELTY (H. T.). — **Long spans of Hudson River bridge** erected by progressive cantilever method. (5 400 words & fig.)

1925 624 .1 (.485)
Engineering News-Record, No. 14, April 2, p. 568.
Deep-water **bridge foundation** of concrete pipe piles (800 words & fig.)

1925 656 .213 (.73)
Engineering News-Record, No. 15, April 9, p. 600.
Plan **railway and ship terminals** for Seattle, Wash. (1 800 words & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 16, April 16, p. 641.
RINDSFOOS (C. S.). — **Plugging a high pressure** tunnel, Buffalo filter plant. (1 700 words & fig.)

1925 624 .63 (.73)
Engineering News-Record, No. 16, April 16, p. 643.
TODD (W. S.). — **Rib-arch concrete highway bridge** over Rock River, Ill. (1 200 words & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 19, May 7, p. 764.
Exhaust-and-supply **ventilation of a long street tunnel.** (2 000 words & fig.)

1925 624. (01 (.73)
Engineering News-Record, No. 20, May 14, p. 804.
**Bridge building** on an Indiana State highway. (2 700 words & fig.)

1925 625 .13 (.73)
Engineering News-Reord, No. 21, May 21, p. 840.
Philadelphia builds **Broad Street subway.** (2 000 words & fig.)

1925 656 .211.4 (.73)
Engineering News-Record, No. 22, May 28, p. 898.
Pennsylvania R. R. Presents **Plans for Philadelphia Station.** (1 100 words & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 24, June 11, p. 966.
Construction methods on six-mile **Moffat tunnel.** (4 000 words, 1 table & fig.)

1925 625 .13 (.73)
Engineering News-Record, No. 25, June 18, p. 1006.
**Widening the Missouri River highway bridge** at Omaha. (2 700 words & fig.)

1925 62. (01
Engineering News-Record, No. 25, June 18, p. 1014.
SLACK (S. B.). & BOYD (J. E.). — Suggests **one-day strength test** for concrete aggregate. (1 400 words & 1 table.)

## Journal of the Institute of Transport. (London.)

1925 656 .23 (01
Journal of the Institute of Transport, February, p. 239.
GIBB (R.). — Principles governing **railway rates.** (13 000 words & tables.)

1925 656 .256 & 656 .257
Journal of the Institute of Transport, March, p. 266.
EDMONDS (C. H. W.). — **Modern traffic and signalling** — with some recent developments. (20 000 words & fig.)

1925 385 .51
Journal of the Institute of Transport, March, p. 290.
DAVIES (H. B.). — The **rights and duties** of transport undertakings. (5 200 words.)

1925 656 .222.6 (.42)
Journal of the Institute of Transport, June, p. 411.
CLOW (W.). — Goods trains services and **time tables.** (7 200 words.)

1925 385 & 621 .14
Journal of the Institute of Transport, July, p. 468.
LAMB (D. R.). — The **co-ordination of rail and road transport.** (22 000 words.)

## Mechanical Engineering. (New York.)

1925 621 .1 (01
Mechanical Engineering, February, p. 103.
Progress in **steam research.** (3 500 words & fig.)

1925 621 .114
Mechanical Engineering, February, p. 109.
Symposium on **lubrication.** (6 000 words, 8 tables & fig.)

1925 621 .165 (.73)
Mechanical Engineering, March, p. 186.
HODGKINSON (F.). — Large **steam turbines.** (3 300 words.)

925 621 .116 (.73)
chanical Engineering, March, p. 193.
'EEBLES (T. A.). — **Combustion control.** (4 800 rds.)

925 621 .116 (.73)
nanical Engineering, March, p. 197.
AVAGE (H. D.). — **Water-cooled furnaces.** (3 900 rds & fig.)

925 669. (01
chanical Engineering, May (section one), p. 339.
'AMMEN (L.). — **Principles of metallurgy of fer-s metals** for mechanical engineers. (7 600 words ig.)

925 669 .1
chanical Engineering, May (section two), p. 393.
IOULTROP (I. E.) & NORRIS (E. W.). — The Ray examination of **steel castings.** (4 000 words ig.)

## Modern Transport. (London.)

925 621 .132.8 (.68)
dern Transport, No. 326, June 13, p. 3.
rticulated locomotives for South African Railways. 00 words & fig.)

925 621 .132.7 (.42)
dern Transport, No. 333, August 1, p. 5.
ew-type petrol-driven locomotive. (800 words ig.)

925 621 132.8 (.592)
ern Transport, No. 336, August 22, p. 3.
ocomotive developments, Burma Railways. (1 300 ls & fig.)

## ceedings, American Society of Civil Engineers. (New York.)

925 624. (01
eed. Amer. Soc. Civil Eng., February, p. 289.
condary stresses in bridges. (5 200 words & fig.)

925 385 .21
eed. Amer. Soc. Civil Eng., February, p. 306.
aterway and railway equivalents. (10 500 words tables.)

925 624 .63 (.73)
eed. Amer. Soc. Civil Eng., March, p. 129.
ogress report of the special committee on concrete reinforced concrete arches. (3 000 words & fig.)

925 721 .3 (01 (.73)
eed. Amer. Soc. Civil Eng., March, p. 392.
nal report of the special committee on stresses in ctural steel. (5 800 words & 1 table.)

925 624. (01 (.73)
eed. Amer. Soc. Civil Eng., March, p. 406.
ROSS (H.), WILSON (W. M.) & THOMSON LAO. — Secondary stresses in bridges. (6 000 words, bles & fig.)

1925 721 .9 (.73)
Proceed. Amer. Soc. Civil Eng., March, p. 422.
CAIN (W.) & ANDREWS (C. B.). — Design of symmetrical concrete arches. (3 000 words, 5 tables & fig.)

1925 625 .14 (01
Proceed. Amer. Soc. Civil Eng., April, p. 469.
Fourth progress report of the special committee to report on stresses in railroad track. (32 500 words, tables & fig.)

1925 624. (01
Proceed. Amer. Soc. Civil Eng., April, p. 644.
GODFREY (E.) & FISHBURN (C. C.). — Secondary stresses in bridges. (3 600 words, 3 tables & fig.)

1925 721 .4
Proceed. Amer. Soc. Civil Eng., April, p. 654.
Design of symmetrical concrete arches. (6 600 words, 2 tables & fig.)

1925 621 .138.2 (.73)
Proceed. Amer. Soc. Civil Eng., May, p. 721.
HALL (H. H.). — Fire-banks for oil storage. (5 000 words & fig.)

1925 691 (.73)
Proceed. Amer. Soc. Civil Eng., May, p. 757.
HATT (W. K.). — The effect of moisture on concrete. (9 800 words, 15 tables & fig.)

1925 721 .1 (01
Proceed. Amer. Soc. Civil Eng., May, p. 884.
Progress report of the special committee to codify present practice on the bearing value of soils for foundations, etc. (6 500 words & fig.)

## Proceedings, Institution of Civil Engineers. (London.)

1925 656 .284 (.54)
Proceed. Institut. of Civil Eng., vol. CCXVIII, p. 2.
NOLAN (T. R.). — Slips and washouts on the Hill Section of the Assam-Bengal Railway. (9 000 words & fig.)

1925 625 .123
Proceed. Instit. of Civil. Eng., vol. CCXVIII, p. 27.
WALKER (R. D.). — Underdrainage, and its application to railway work. (18 500 words & fig.)

1925 624. (01
Proceed. Instit. of Civil Eng., vol. CCXVIII, p. 181.
REMFRY (D. H.). — The interaction in bridgework of the deck system on the main girders, and the consequent modification of stresses therein. (13 500 words, tables & fig.)

1925 624 .2 (01
Proceed. Instit. of Civil Eng., vol. CCXVIII, p. 225.
INGLIS (C. E.). — Theory of transverse oscillations in girders, and its relation to live-load and impact allowances. (35 500 words, 2 tables & fig.)

## Proceedings, Institution of Mechanical Engineers. (London.)

1925 62. (01 & 621 .93
Proceed. Instit. of Mechan. Eng., No. 2, p. 141.
ROSENHAIN (W.). — Report on flow and rupture of metals during cutting. (3 900 words, 9 tables & fig.)

1925 62. (01 & 621 .93
Proceed. Instit. of Mechan. Eng., No. 2, p. 175.
STANTON (T. E.) & HYDE (J. H.). — Report on an **experimental study of the forces exerted on the surface of a cutting tool.** (17 500 words, 1 table & fig.)

1925 621 .114
Proceed. Instit. of Mechan. Eng., No. 2, p. 235.
DAHLERUS (J. B.). — **Anti-friction bearing applications** for heavy duty. (37 000 words, 6 tables & fig.)

1925 62. (01 & 621 .93
Proceed. Instit. of Mechan. Eng., No. 2, p. 357.
COKER (E. G.). — Report on the action of **cutting tools.** (5 600 words, 4 tables & fig.)

1925 62. (01 & 621 .93
Proceed. Instit. of Mechan. Eng., No. 2, p. 383.
SMITH (D.) & LEIGH (A.). — **Experiments with lathe tools on fine cuts,** and some physical properties of the tool steels used and metal operated upon. (23 400 words, 1 table & fig.)

1925 62. (01
Proceed. Instit. of Mechan. Eng., No. 3, p. 611.
HANKINS (G. A.). — Report on the effects of adhesion between the indenting tool and the material in **ball and cone indentation hardness tests.** (6 700 words, 19 tables & fig.)

1925 62. (01
Proceed. Instit. of Mechan. Eng., No. 3, p. 647.
SHIRES (G. A.). — Some practical aspects of the **scratch test for hardness.** (17 400 words, 2 tables & fig.)

## Proceedings, Institution of Railway Signal Engineers. (Manchester.)

1925 656 .257
Proceed. Inst. Ry. Signal Eng., part 1, Febr.-Aug., p. 36.
GRIFFITHS (R. S.). — The double wire system of **mechanical signalling.** (17 000 words & fig.)

1925 656 .256
Proceed. Inst. Ry. Signal Eng., part 1, Febr.-Aug., p. 79.
DELL (R). — Some recent developments in A. C. **track circuits.** (8 500 words & fig.)

1925 656 .256.2
Proceed. Inst. Ry. Signal Eng., part 1, Febr.-Aug., p. 103.
LASCELLES (T. S.). — **Lock and block.** (10 600 words, 1 table & fig.)

## Railway Age. (New York.)

1925 313 .385 (.73)
Railway Age, No. 1, January 3, p. 52.
PARMELEE (J. H.). — A **statistical review** of the railroad year 1924. (7 300 words, 7 tables & fig.)

1925 656 .253 (.73)
Railway Age, No. 1, January 3, p. 97.
DUNN (J. H.). — **Automatic train control** progress. (3 500 words, 2 tables & fig.)

1925 385. (09.3 (
Railway Age, No. 1, January 3, p. 114.
FRASER (W. H.). — 100 years of **British railw**
(3 500 words, 5 tables & fig.)

1925 621 .
Railway Age, No. 2. January 10, p. 177.
JONES (G. F.) & HALE (T. L.). — **Turbo elec condensing locomotive.** (2 200 words & fig.)

1925 656 .253 (.
Railway Age, No. 2, January 10, p. 183.
Great Northern installs **train control.** (3 000 wo & fig.)

1925 621 .335 (.
Railway Age, No. 3, January 17, p. 223.
N. Y. C. **electric freight locomotives.** (1 000 wo & fig.)

1925 625 .142.2 (.73) & 691 (.
Railway Age, No. 5, January 31, p. 310.
**Treating five charges of timber** in eleven hours. (2 words & fig.)

1925 621 .335 (.
Railway Age, No. 5, January 31, p. 321.
STUMPF (J.). — **Diesel-electric locomotive** for Russian Government. (2 200 words & fig.)

1925 621 .132.5 (.
Railway Age, No. 6, February 7, p. 353.
D. & H. **high pressure locomotive.** (2 800 words & fi

1925 621 .132.8 (.
Railway Age, No. 7, February 14, p. 401.
**Two-car gasoline motor train** for local service main line. (900 words & fig.)

1925 621 .133.7 (.
Railway Age, No. 8, February 21, p. 468.
PLANT (L. G.). — **Locomotive feedwater heati** (3 400 words & fig.)

1925 624 .1 (.
Railway Age, No. 10, March 7, p. 557.
BRYSON (G. G). — **Tamping, dragging** and rolli consolidates new fill. (3 000 words & fig.)

1925 656 .257 (.
Railway Age, No. 15, March 14, p. 733.
MORGAN (H. G.). — **Signaling two tracks** to ca city. (1 400 words & fig.)

1925 625 .13 (.
Railway Age, No. 16, March 21, p. 781.
Large concrete plant employed on **track elevati work.** (2 500 words & fig.)

1925 725 .33 (.
Railway Age, No. 17, March 28, p. 823.
Union Pacific builds large **shops of timber and sh iron.** (3 200 words & fig.)

1925 621 .33 (.
Railway Age, No. 17, March 28, p. 836.
Bombay suburban **electrification.** (2 200 words & fi

1925 625 .13 (.73)
Railway Age, No. 18, April 4, p. 875.
ARMSTRONG (A. S.). — **Rebuilding the White River bridge.** (2 900 words & fig.)

1925 656 .256 (.73)
Railway Age, No. 18, April 4, p. 881.
POST (W. M.). — **Relieving congestion by signals** on the Pennsylvania. (2 700 words & fig.)

1925 725 .45 (.73)
Railway Age, No. 19, April 11, p. 923.
Central of Georgia **coach shops** have efficient layout. (1 800 words & fig.)

1925 621 .131.1 (.73)
Railway Age, No. 20, April 18, p. 971.
**Long engine runs** on the Burlington. (2 500 words, 5 tables & fig.)

1925 656 .257 (.73)
Railway Age, No. 21, April 25, p. 1021.
DE MERITT (E. B.). — **Train orders** eliminated by signals on busy single track. (1 700 words & fig.)

1925 656 .254 (.73)
Railway Age, No. 22, May 2, p. 1095.
The **automatic printing telegraph** for intra-city business. (1 200 words, 1 table & fig.)

1925 621 .138.2 (.73)
Railway Age, No. 22, May 2, p. 1097.
New **coaling station** has car loading facilities. (1 200 words & fig.)

1925 621 .332 (.71)
Railway Age, No. 22, May 2, p. 1099.
WALKER (E. B.). — New **catenary construction** on the Canadian National. (2 200 words & fig.)

1925 621 .335 (.73) & 621 .4 (.73)
Railway Age, No. 23, May 9, p. 1135.
**Gas electric car** for the New Haven. (2 600 words & fig.)

1925 656 .257 (.73)
Railway Age, No. 23, May 9, p. 1143.
**Car retarders** in hump yard effective in winter. (1 700 words & fig.)

1925 621 .134.1 (.73)
Railway Age, No. 24, May 16, p. 1197.
**Three-cylinder locomotives** on American railroads. (2 900 words, 7 tables & fig.)

1925 621 .138.5 (.73) & 621 .139 (.73)
Railway Age, No. 25, May 23, p. 1263.
SILLCOX (L. K.). — **Economics of shopping locomotives.** (4 200 words & fig.)

## Railway Engineer. (London.)

1925 621 .9 (.42)
Railway Engineer, April, p. 113.
New **machine tools** at Doncaster works, London & North Eastern Railway. (4 700 words & fig.)

1925 656 .253 (.42)
Railway Engineer, April, p. 130.
Harrow to Rickmansworth **signalling,** Metropolitan and Great Central Joint line. (1 900 words & fig.)

1925 624. (01 (.51)
Railway Engineer, April, p. 133.
Standardisation of **bridge design** on Chinese Government Railways. (1 600 words & fig.)

1925 621 .7 (.42)
Railway Engineer, May, p. 149.
A modern **railway wagon building works.** (4 800 words & fig.)

1925 621 .132.8 (.73)
Railway Engineer, May, p. 162.
The Dunlop **superheated « aero-steam » locomotive.** (1 300 words & fig.)

## Railway Engineering & Maintenance. (Chicago.)

1925 625 .143.3
Railway Engineering & Maintenance, February, p. 44.
GREENE (A. L.). — What the lack of standardization of **track bolts costs.** (3 000 words & fig.)

1925 625 .142.2 & 691
Railway Engineering & Maintenance, February, p. 57.
**Wood Preservers** discuss problems at annual convention. (8 200 words, 1 table & fig.)

1925 621 .138 (.73)
Railway Engineering & Maintenance, April, p. 139.
HAYDOCK (C.). — Pennsylvania constructs large dam to insure **water supply.** (2 400 words & fig.)

1925 625 .154 (.73)
Railway Engineering & Maintenance, April, p. 145.
TOWNE (E. W.). — Renewing a **turntable** in five hours. (700 words & fig.)

1925 625 .144.4 (.73)
Railway Engineering & Maintenance, April, p. 148.
Canadian Pacific **ballasts track** at rate of a mile a day. (1 200 words & fig.)

1925 625 .13 (.73)
Railway Engineering & Maintenance, April, p. 154.
CRAMER (F. H.). — Thorough plan insures success of **viaduct erection.** (1 300 words & fig.)

1925 625 .172 (.73)
Railway Engineering & Maintenance, May, p. 181.
Santa Fe makes exhaustive study of chemical **weed killing.** (2 300 words, 1 table & fig.)

1925 625 .13 (.73)
Railway Engineering & Maintenance, May, p. 187.
SALMON (J. M.). — Falsework permits **erection of bridge** without obstructing traffic. (800 words & fig.)

1925 725 .33 (.73)
Railway Engineering & Maintenance, May, p. 191.
New **water facilities** at Russell, Ky. insure adequate supply. (2 300 words & fig.)

**1925** 624 .7 (.73)
Railway Engineering & Maintenance, June, p. 223.
WATSON (T. P.). — Pennsylvania engineers design **concrete mixtures.** (3 400 words & fig.)

## Railway Gazette & Railway News. (London.)

**1925** 621 .132.8 (.43) & 621 .43 (.43)
Railway Gazette & News, No. 3, January 16, p. 76.
400 H. P. **Diesel locomotive.** (800 words & fig.)

**1925** 621 .132.8 (.68)
Railway Gazette & News, No. 4, January 23, p. 102.
« **Garratt** » **locomotives** on the New Cape Central Railway. (1 000 words & fig.)

**1925** 621 .33 (.54)
Railway Gazette & News, No. 4, January 23, p. 107.
**Suburban railway electrification** on the G. I. P. Railway. (2 300 words & fig.)

**1925** 621 .33 (.68)
Railway Gazette & News, No. 5, January 30, p. 129.
HOY (Sir William W.). — **Railway electrification** in South Africa. (4 600 words, 1 table & fig.)

**1925** 621 .138 (.42)
Railway Gazette & News, No. 6, February 6, p. 164.
**Hot-water washing** for locomotive boilers. (1 300 words, 1 table & fig.)

**1925** 621 .132.8 (.481)
Railway Gazette & News, No. 7, February 13, p. 198.
**Petrol-driven rail motor vehicles** for the Norvegian State Railways. (700 words & fig.)

**1925** 621 .132.8
Railway Gazette & News, No. 8, February 20, p. 234.
The **internal-combustion locomotive.** (3 500 words.)

**1925** 385. (09.3 (.42)
Railway Gazette & News, No. 11, March 13, p. 359.
The **railway jubilee of 1875.** (8 000 words & fig.)

**1925** 621 .33 (.42)
Railway Gazette & News, No. 12, March 20, p. 401.
The world's greatest **suburban electrification.** (2 900 words & fig.)

**1925** 385 .4 (.931)
Railway Gazette & News, No. 12, March 20, p. 405.
Royal commission on **New Zealand railways.** (2 400 words, 2 tables & fig.)

**1925** 621 .33 (.42)
Railway Gazette & News, No. 14, April 3, p. 474.
Southern Railway **electrification.** (1 000 words & fig.)

**1925** 385. (09.2
Railway Gazette & News, No. 15, April 10, p. 506.
**Sir William Mitchell Acworth,** M. A., K. C. S. I. (900 words & portrait.)

**1925** 656 .222.5 (.42)
Railway Gazette & News, No. 16, April 17, p. 528.
**Manipulation of heavy passenger traffic** at Wembley. (1 400 words, 3 tables & fig.)

**1925** 385 .113 (.42)
Railway Gazette & News, No. 17, April 24, p. 555.
**Financial results** of the group railway companies in 1924. (4 000 words & 30 tables.)

**1925** 621 .132.8 (.931)
Railway Gazette & News, No. 19, May 8, p. 638.
A new steam rail car. (1 200 words & fig.)

**1925** 656 .213 (.42)
Railway Gazette & News, No. 19, May 8, p. 643.
Transport at **Messrs. Lyons' works** at Greenford. (1 300 words & fig.)

**1925** 656 .25 (.4)
Railway Gazette & News, No. 22, May 29, p. 734.
PALMER (C. H.). — **Signalling** in Germany and other European countries. (3 600 words & fig.)

**1925** 385. (06.119
Railway Gazette & News, No. 23, Juni 5, p. 765.
The **British Railway Centenary.** (4 000 words & tables.)

**1925** 621 .132.5 (.42)
Railway Gazette & News, No. 26, June 26, p. 880.
Noteworthy **locomotive developments L. N. E. R.** (1 300 words & fig.)

**1925** 385. (06.112
Railway Gazette & News, No. 1, July 3, p. 7.
**International Railway Congress** in London. (25 700 words.)

**1925** 621 .132.3 (.42)
Railway Gazette & News, No. 1, July 3, p. 45.
New **express locomotives** for the Southern Railway. (300 words & fig.)

**1925** 385. (06.4 (.42) & 385. (09.3 (.42)
Railway Gazette & News, No. 2, July 10, p. 81.
The **railway centenary** celebrations. (11 400 words & fig.)

**1925** 621 .134.3 (.42)
Railway Gazette & News, No. 2, July 10, p. 90.
The three-cylinder **high-pressure locomotive.** (2 200 words & fig.)

**1925** 621 .33 (.42)
Railway Gazette & News, No. 3, July 17, p. 113.
**Suburban electrification** on the Southern Railway. (3 400 words & fig.)

## Railway Magazine. (London.)

**1925** 656 .222.1 (.42)
Railway Magazine, January, p. 27.
— — February, p. 117.
— — March, p. 193.
— — April, p. 285.
— — May, p. 359.
— — June, p. 463.
ALLEN (C. J.) — **British locomotive practice** and performance. (30 300 words, tables & fig.)

1925 385. (09.3 (.42)
Railway Magazine, January, p. 41.
1825-1925. — The romance of the **railway centenary.** Building up the British railway system. (6 200 words & fig.)

1925 656 .211 (.42)
Railway Magazine, May, p. 337.
GAIRNS (J. F.). — **Notable railway stations** and their traffic. (5 800 words & fig.)

1925 385. (09.3 (.42)
Railway Magazine, May, p. 387.
The **Railway Jubilee** of 1875. (3 200 words & fig.)

## Railway Mechanical Engineer. (New York.)

1925 621 .335 (.73)
Railway Mechanical Engineer, January, p. 5.
JONES (G. F.) & HALE (T. L.). — **Ramsay turbo-electric locomotive.** (3 200 words & fig.)

1925 621 .132.5 (.73)
Railway Mechanical Engineer, February, p. 79.
The « Horatio Allen », **a high pressure locomotive.** (2 800 words & fig.)

1925 621 .7 (.73)
Railway Mechanical Engineer, March, p. 165.
Southern builds modern equipped **loomotive shops.** (5 000 words & fig.)

1925 625 .245 (.73)
Railway Mechanical Engineer, April, p. 202.
N. Y. C. all-steel **dynamometer car.** (1 900 words & fig.)

1925 621 .133.7 (.73)
Railway Mechanical Engineer, April, p. 206.
PLANT (L. G.). — **Locomotive feedwater heating.** (2 000 words & fig.)

1925 625 .251 (.43)
Railway Mechanical Engineer, April, p. 209.
German State Railway's **brake tests.** (1 800 words & fig.)

1925 625 .232 (.73)
Railway Mechanical Egineer, April, p. 223.
**Suburban cars** for the D. L. & W. (1 500 words & fig.)

1925 621 .131.1 (.73)
Railway Mechanical Engineer, May, p. 261.
Long **locomotive runs** on the C. B. & Q. (2 500 words, 5 tables & fig.)

1925 621 .132.5 (.73)
Railway Mechanical Engineer, May, p. 267.
High power **2-8-4 type locomotive.** (2 900 words, 2 tables & fig.)

1925 625 .26 (.73)
Railway Mechanical Engineer, May, p. 280.
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1925 621 .134.1 (.73)
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1925 621 .132.8 (.434)
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1925 625 .13 (.73)
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**1925** 656 .253
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**1925** 725 .33 (.73)
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**1925** 621 .132.8 (.73)
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**1925** 621 .33 (.73)
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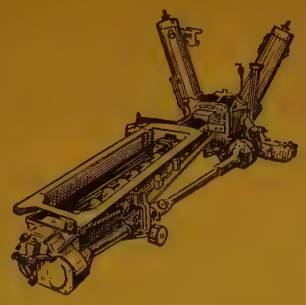

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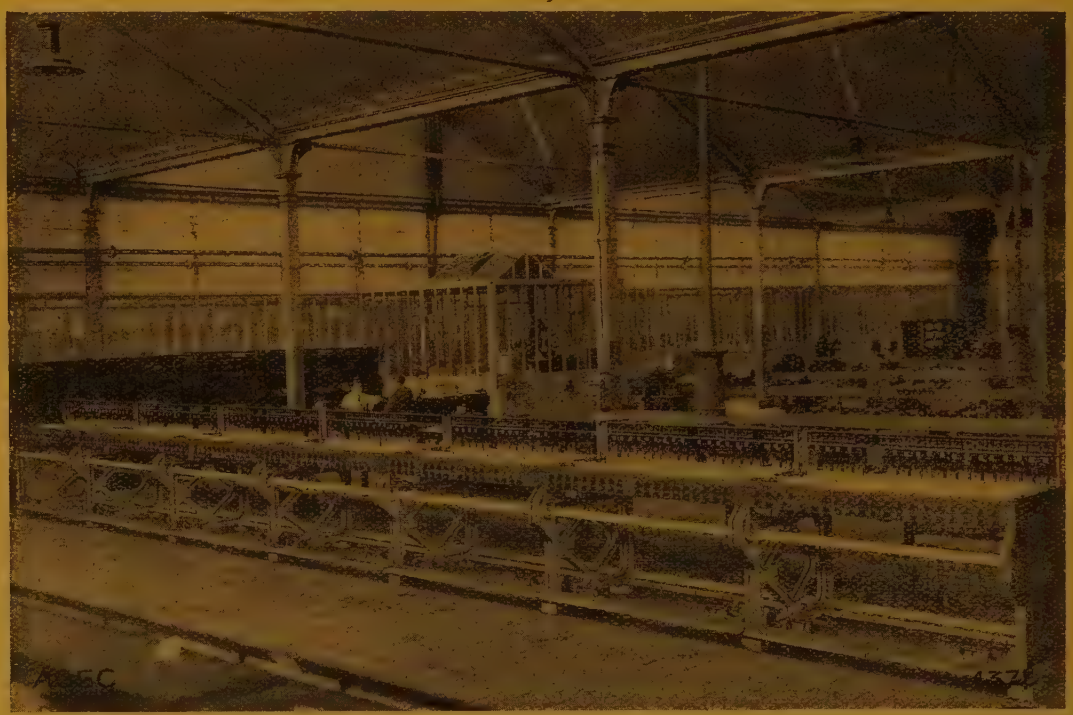

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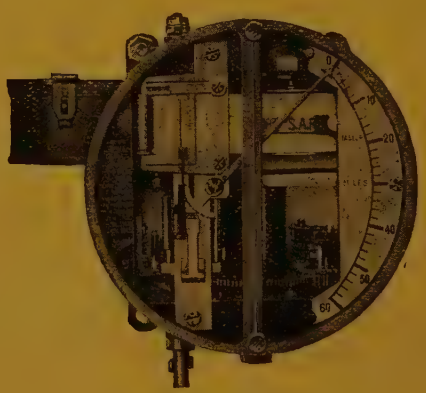

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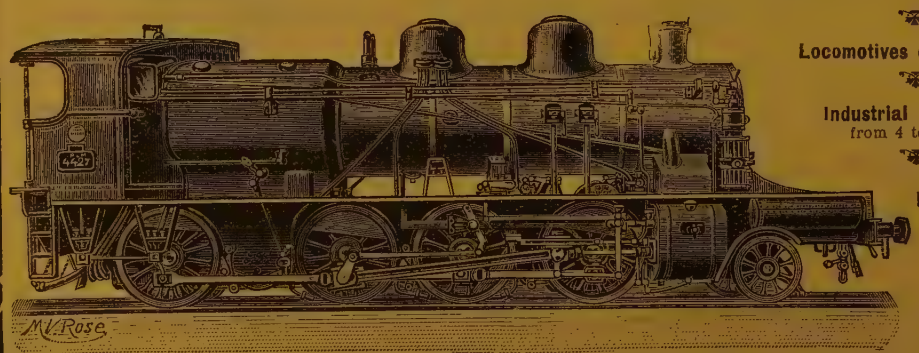


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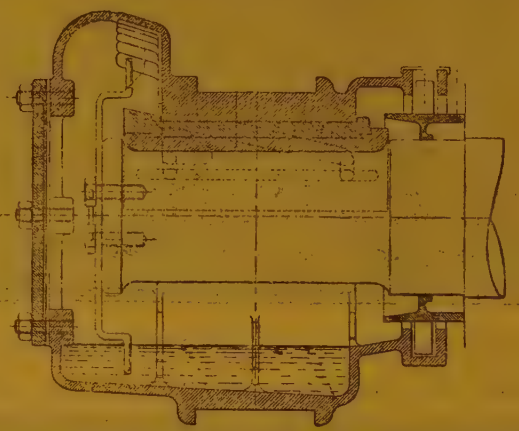

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